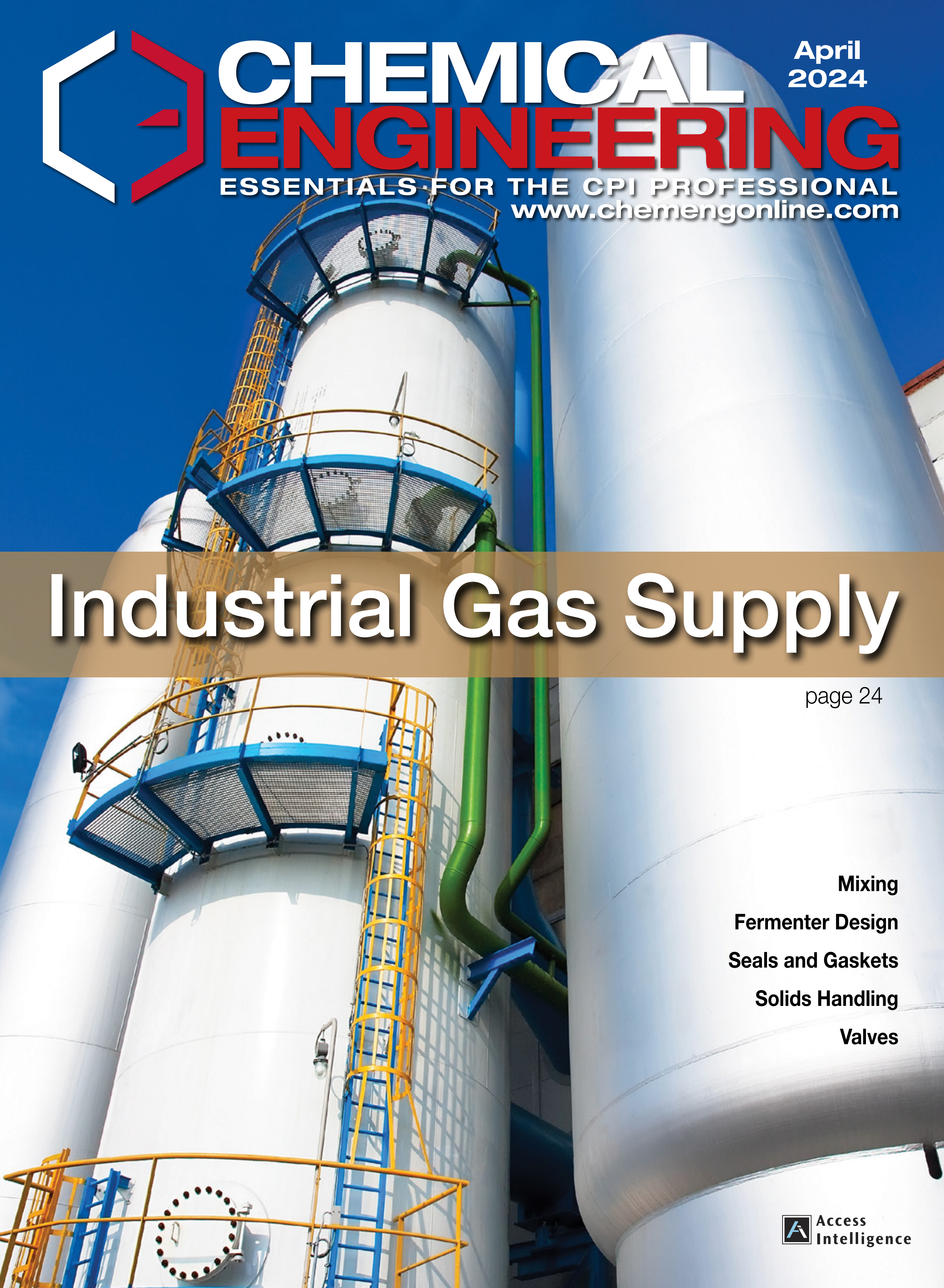

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Editor's Page

Disclosing climate risks

Last month, the U.S. Securities and Exchange Commission (SEC; www.sec.gov) finalized rules [*1*] that require registrants to disclose information about climate-related risks in their annual reports and registration statements. Recognizing that climate-related risks can affect a company's business and financial position, the SEC rules are intended to give investors "more consistent, comparable and reliable information about the financial effects of climate-related risks on a registrant's operations and how it manages those risks." The new rules were first proposed two years ago, in March of 2022. Since that time, the SEC has considered more than 24,000 comment letters about the initial proposal before voting on, and passing a modified final ruling on March 6, 2024. The final rules will become effective 60 days after publication in the Federal Register, and compliance dates will be phased in, depending on the registrant's filer status.

The final rules

The final rules require registrants to disclose information about climate-related risks that materially impact business strategy, operations or finances. Some disclosures related to severe weather events and other natural conditions are also required. In its Fact Sheet about the rules, the SEC states that the rules require the following, among other things, to be disclosed: "material climate-related risks; activities to mitigate or adapt to such risks; information about the registrant's board of directors' oversight of climate-related risks and management's role in managing material climate-related risks; and information on any climate-related targets or goals that are material to the registrant's business, results of operations, or financial condition."

In addition, some registrants are required to disclose Scope 1 and Scope 2 greenhouse gas (GHG) emissions. Scope 1 includes direct GHG emissions from sources that are controlled or owned by an organization. Examples are emissions from fuel combustion from boilers, furnaces and vehicles. Scope 2 refers to indirect GHG emissions, for example those that are associated with the purchase of electricity, steam, heat and cooling. Scope 3 emissions result from an organization's upstream and downstream activities [*2*].

The proposed rules included requirements to report Scope 3 emissions, but this requirement was dropped in the final rules. In response to the final rules announcement, the American Chemistry Council (ACC; www.americanchemistry.com) states "While it will take some time to digest the lengthy rule package, we're pleased that the Commission has removed the proposed requirement that companies quantify and report on 'Scope 3' emissions. ACC members supply critical chemistries used in the value chains of nearly every sector of the economy. This requirement posed unique challenges for the chemical sector while providing little value to investors." The ACC also points out that its members already track Scope 1 and 2 emissions through its Responsible Care program, and it further states "ACC and its members are committed to being partners and solution providers in supporting a sensible path to a lower-emissions economy. We vigorously participated in this rulemaking and look forward to engaging on proposals with significant impacts for companies and sustainability efforts." ■

Dorothy Lozowski, Editorial Director

1. The Enhancement and Standardization of Climate-Related Disclosures: Final Rules can be found at www.sec.gov
2. Source for the definition of emission scopes: U.S. Environmental Protection Agency; www.epa.gov

A new super-duplex tube tailored for acids

Last month at the AMPP Annual Conference + Expo 2024 (New Orleans, La.; March 3–7), Alleima AB (Sandviken, Sweden; www.alleima.com) introduced SAF 3006 (UNS S83071), a high-alloy duplex (austenitic-ferritic) stainless steel tailored to enhance corrosion resistance in acidic and caustic environments. The new alloy is an upgrade to traditional super-duplex stainless steels. "SAF 3006 will complement SAF 2507 in dealing with corrosive conditions in heat-exchanger tubing exposed to hydrochloric, sulfuric, formic or other acids. This is our super duplex tailored to resist acids," says Eduardo Perea, market & product manager EMEA at Alleima Tube Division. The main application is for heat exchangers in the chemical and petrochemicals industries. "Applications may include caustic evaporators, acid coolers and evaporators," says Perea.

"Previously, most of our duplexes were developed with chloride resistance as the main focus, with high PRE (pitting resistance equivalent) levels to resist pitting and crevice corrosion. Resistance to acidic conditions was less prioritized," explains Daniel Gullberg, manager of product development CRA (corrosion-resistant alloys). "Now, we have fine-tuned the chemical composition to resist acidic environments better. This involves a high chromium content of 30% and a molybdenum level of 3.2% to maintain good structural stability and balancing of the alloying elements," he says

"SAF 3006 is an upgrade over existing duplex grades facing higher-than-desired corrosion rates and where extended equipment lifetime is wanted. You get all the benefits of traditional duplex steel in terms of strength, lighter weight and cost-efficiency, but tailored to resist acids. It can be used in acid-production plants with or without seawater cooling," says Oscar Öhlin, R&D Engineer at Alleima.

Alleima will supply seamless tube and pipe in SAF 3006 in standard heat-exchanger dimensions.

Edited by:
Gerald Ondrey

CO_2 LIQUEFACTION

Last month, Linde Engineering (Pullach, Germany; www.linde-engineering.com) signed a contract with Yara International ASA (Oslo, Norway; www.yara.com) to build a world-scale carbon dioxide liquefaction plant in Sluiskil, the Netherlands.

The Sluiskil project forms a key part of Yara's clean ammonia initiative, in which 800,000 tons/yr of CO_2 will be captured, liquefied, loaded onto special ships and then stored permanently below the seabed off the coast of western Norway. The CO_2-liquefaction

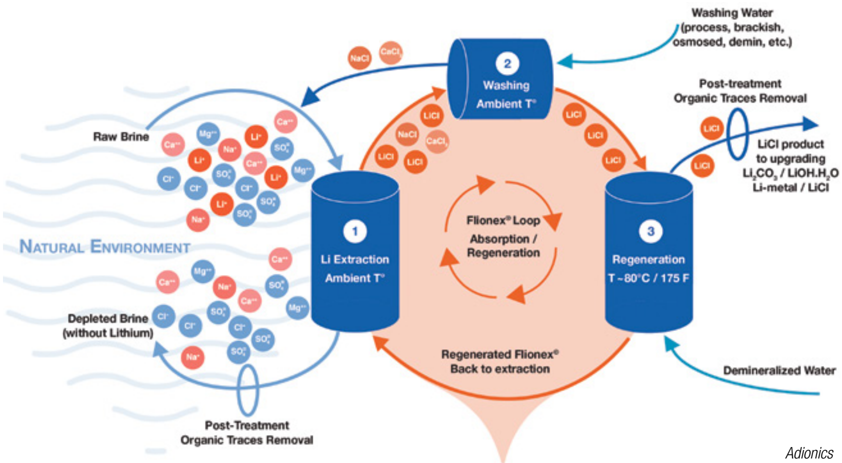
(Continues on p. 6)

Recovering lithium with thermal-swing liquid-liquid deionization

Much of the planet's lithium is contained in brine, but the concentration is often quite low, making it difficult to efficiently extract lithium — typical extraction technologies may only demonstrate 30–60% yield. Adionics (Les Ulis, France; www.adionics.com) has developed a proprietary liquid-extraction medium called Flionex to be used in a patented thermal-swing liquid-liquid deionization process to enable extremely high recovery and selectivity for lithium. When raw brine is brought into contact with Flionex, all lithium is extracted, little sodium and little calcium are co-extracted, while other elements, such as potassium, boron, magnesium and sulfates, are rejected. The loaded medium is then washed with cool water to remove the undesired sodium and calcium, which are partially desorbed, while lithium remains in the organic phase. Finally, the loaded Flionex is contacted with heated demineralized water. Only the lithium and chloride are released into the aqueous phase, forming a concentrated stream of LiCl. The newly regenerated Flionex is sent back to the extraction phase.

"It is important to highlight that Adionics' process does not require any chemical input throughout the process besides a limited amount of freshwater. This technology guarantees lithium recovery up to 99% with purity up to 99%," says François-Michel Colomar, an engineer and Adionics' head of external relations. Furthermore, he notes, the extraction technology can be adapted to recover lithium from different brine sources, including geothermal sites, industrial effluents and battery-recycling facilities. Notably, the selectivity makes the process suitable for magnesium- and sulfate-rich brines, which cannot be processed using typical lithium-extraction methods. The depleted brine can be reinjected to the Salar without any pre-treatment, since the technology does not change brine pH, says Colomar.

The company recently completed extensive testing of the technology (over 1,500 h) at a pilot plant in Chile's Salar de Atacama, producing 99% pure LiCl. The tests showed stable operation with a wide range of brine concentrations at fluctuating temperatures. The company has also built a 250-ton/yr demonstration plant, which is to be installed in Argentina, and initial engineering work is underway for a 20,000-ton/yr commercial-scale plant.



Adionics

plant will be built on-site next to Yara's existing ammonia plant. After startup in 2026, it will be a part of one of the first commercial carbon-capture-storage (CCS) ventures in Europe.

SCRUBBER PILOT

Metso Corp. (Espoo, Finland; www.metso.com) has installed a fully automated multi-purpose scrubber pilot plant at its R&D center in Frankfurt am Main, Germany. The new plant will be used for developing and optimizing gas-cleaning processes. The first focus will be on the development of simultaneous scrub-

(Continues on p. 8)

Membrane-free water electrolysis

Researchers at KTH Royal Institute of Technology (Stockholm, Sweden; www.kth.se) have developed a way to decouple the production of hydrogen and oxygen in water electrolysis, thereby reducing the explosion potential of mixing the two gases. The method, described in a recent issue of *Science Advances*, combines the electrocatalytic reactions of an electrolyzer with a capacitive-storage mechanism.

In a conventional alkaline electrolyzer, the cathode and anode are separated by an ion-permeable membrane. When an electric current is applied, water reacts at the cathode by forming H_2 and OH^- ions, which diffuse through the barrier to the anode to produce O_2. But the barrier causes resistance, and if the electric charge fluctuates, the risk of an explosive mix between O_2 and H_2 is heightened.

To avoid this, one of the electrodes is replaced with a super capacitive electrode made from carbon. When the electrode is negatively charged and producing H_2, the super capacitor stores energy-rich OH^- ions. When the direction of current is reversed, the super capacitor releases the absorbed OH^-, and O_2 is produced at the now-positive electrode. "One electrode does the evolution of both oxygen and hydrogen," explains Joydeep Dutta, professor of applied physics at KTH. "It's a lot like a rechargeable battery producing H_2 — alternately charging and discharging. It's all about completing the circuit."

According to the *Science Advances* article, an energy efficiency of 69% lower heating value (48 kWh/kg) at 10 mA/cm^2 (5 cm × 5 cm cell) was achieved using a cobalt-iron phosphide bifunctional catalyst with 99% Faradaic efficiency at 100 mA/cm^2. The researchers also report that laboratory tests showed no apparent electrode degradation as a result of long-term tests, which is important for commercial applications.

Dutta and Esteban Toledo, a doctoral student at KTH who co-authored the paper, have patented the system. With support from KTH Innovation, a company, Caplyzer AB (Stockholm, Sweden; www.caplyzer.com), was already formed in 2021 to scale up the technology.

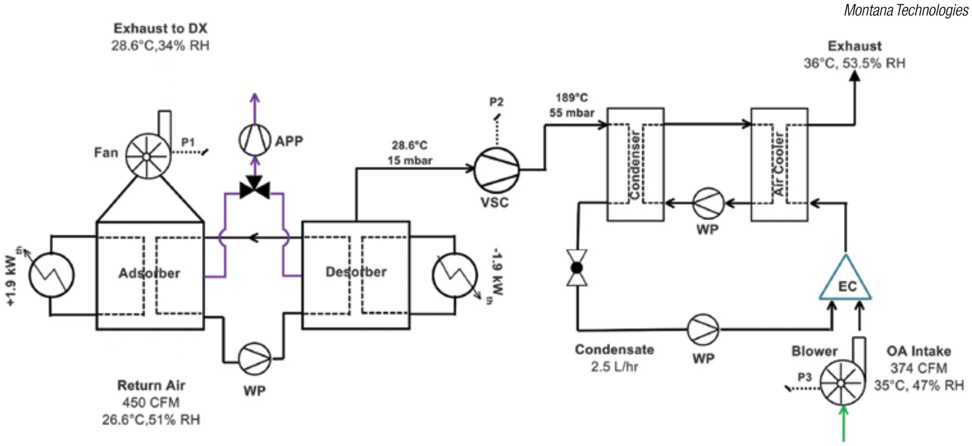
This cooling and water-harvesting system requires no heat

A novel technology for cooling and dehumidification is nearing commercialization through several strategic partnerships, including GE Vernova, BASF and Carrier Global. Montana Technologies' (Ronan, Mont.; www.mt.energy) AirJoule technology employs a metal-organic-framework (MOF) desiccant material that exhibits higher water-uptake capacity and faster atmospheric water extraction when compared to traditional desiccant systems, and with significantly reduced energy consumption. "When desiccant dehumidifier systems remove water from air, a significant heat of adsorption is naturally generated that up to now has been transferred to the air stream and warms it up. In addition, most desiccant systems require adding even more external heat to regenerate the desiccant media, which is often added to the system's cooling load. With AirJoule, we use a pressure-swing approach and do not introduce any external heat. In addition, we capture that heat of adsorption and use it for regeneration. We basically have a net-zero thermal energy balance when extracting water from an airstream," explains Pete McGrail, chief technology officer of Montana Technologies. The AirJoule system is configured as two chambers working in tandem. As humid air is drawn into one chamber, the MOF media adsorbs water vapor. Simultaneously, the heat of adsorption is transferred to the other chamber to begin regenerating the media. "Air is flowing through one chamber all the time, while the other chamber is being regenerated under a modest vacuum," says McGrail. The system cycles between chambers every 5–10 min.

However, there are limitations on the system's ability to compress water vapor while maintaining its energy balance. "We're compressing the water vapor just enough to condense it. We have designed specialized equipment to handle low-pressure water vapor and minimize the energy requirement," adds McGrail. Once the water is a liquid, it takes a trivial amount of energy to bring it up to atmospheric pressure for discharge and use.

Many applications for AirJoule are in HVAC and water-heating installations, but the company has also seen interest in applying the technology as a replacement for evaporative cooling systems in aluminum-smelting and data-center applications.

Montana Technologies



bing of SO_2 and oxides of nitrogen (NOx) at low temperatures.

The pilot plant features modern online sensors for the measurement of an extensive set of gas and liquid properties. The process control system will allow the development of reliable process models for designing industrial-sized plants and will support further process optimization and advanced digitalization solutions.

LIVE SENSING

At Anuga FoodTec last month (Cologne, Germany; March 19–22), GEA AG (Düsseldorf, Germany; www.gea.com) introduced NiSoMate, a new live-product monitoring sensor system for homogenizers. NiSoMate is a patented sensor-based technology for product control during the homogenization process. Liquids are continuously analyzed inline for their consistency and quality in real time. This enables direct adjustment of system performance, such as homogenization pressure, resulting in more efficient use of energy in the production process. By implementing this new sensor technology, traditional sampling methods are bypassed, significantly saving time, GEA says.

The sensor system employs an ultrasound-based "beamforming array" technology that allows physical product properties, such as density, consistency change and dilution, to be derived. These parameters can be read by an external process-control system, which can then take appropriate actions. Consequently, operators can monitor the process directly on the production line and adjust the performance of the system accordingly, without having to wait for laboratory samples results.

METALS RECOVERY

Last month, Boston Metal inaugurated the first facility for its molten oxide electrolysis (MOE) technology platform to recover high-value metals from mining waste in Brazil. This deployment is a major milestone for Boston Metal's technology and operations as it works toward commercializing MOE for "green" steel in 2026.

Boston Metal's MOE technology — the same platform that will eventually be used in commercial deployments of its green steel solution — uses electricity to se-

(Continues on p. 9)

A control room with generative-AI capabilities

In January, specialty materials maker Celanese Corp. (Irving, Tex.; www.celanese.com) beta-launched a remote-operations control room (ROCR) that allows hands-free queries of plant data for faster data gathering and decision-making. The ROCR leverages recent advances in generative-artificial intelligence (gen-AI)-powered natural language processing.

In the ROCR, large-language models (LLM) overlay the plant's data, such that the AI-driven language models enable users to request and manipulate plant data and information using only conversational language. Inside the ROCR, a 10-ft x 6-ft multi-screen display shows the current plant situation, and, using verbal requests and commands, plant operators can ask the system to retrieve asset and process information to address problems or optimize operations.

Located at the Celanese facility in Clear Lake, Tex. and developed in partnership with industrial software maker Cognite AS (Oslo, Norway; www.cognite.com), the ROCR provides a "centralized view of Celanese's contextualized industrial data, alongside a deterministic generative AI copilot," Cognite says. "This allows Celanese to find cross-data source insights to understand and solve safety, reliability and quality risks across the operation in real time," according to the companies.

Initial impressions of the ROCR beta launch have been positive. Celanese digital manufacturing director Ibrahim Al-Sayed says the biggest benefit has been from increased productivity. "The system has cut down on the time required for making decisions and solving problems that arise," Al-Sayed says.

The ROCR beta launch represents the culmination of two years of work on data contextualization that allows the LLM to identify the correct data and manipulate it in a way that communicates the information that is needed.

Following the successful rollout, the partners are working to scale the capabilities to multiple locations and refine its capabilities.

Carbon-fiber-reinforced polymer boosts interfacial adhesion and recyclability

The high strength-to-weight ratio and robust mechanical properties of carbon-fiber-reinforced polymers (CFRPs) make them attractive for use in wind-power turbine blades, automobile components, and in airplanes and spacecraft. However, challenges — such as weak interfacial adhesion and poor recyclability — remain. A team of researchers at Oak Ridge National Laboratory (ORNL; Oak Ridge, Tenn.; www.ornl.gov) has synthesized a new type of CFRP aimed at overcoming these challenges.

The approach taken by the researchers was to incorporate a covalent adaptive network (CAN) into the polymer matrix in ways that mimic natural composite materials in marine mollusks. CANs contain dynamic covalent bonds that can undergo exchange reactions to rearrange the network structures. CANs are incorporated to make a dynamic cross-linked thermoset polymer, known as a vitrimer, which can change its topology upon heating, the researchers say.

The ORNL team developed a boronic-ester-functionalized triblock copolymer and dynamic multidiol cross-linker to prepare the vitrimer resin. They functionalized the carbon fiber surface using pinacol (a diol), which can form dynamic covalent bonds with the boronic ester group on the polymer matrices, according to ORNL. This exchangeable cross-linking improves the bonding between fiber and polymer.

"The [carbon] fiber and the polymer have a very strong interfacial adhesion due to the dynamic bonds," says ORNL chemist Tomonori Saito, who led with study with ORNL's Md Anisur Rahman. The interface locks materials together through covalent interactions and unlocks them on demand using heat or chemistry.

The dynamic crosslinking also allowed the researchers to recycle the CFRP without losing mechanical properties. Upon recycling, "we recover 100% of the starting materials — the crosslinker, the polymer, the fiber," Rahman said. And "our composite's strength is almost two times higher than a conventional epoxy composite," he adds. The ORNL scientists found that the degree of dynamic crosslinking (around 5%) is important — excessive crosslinking embrittles the polymer.

The ORNL team is working on reducing costs of the material to optimize potential commercial applications.

Another step forward for new technologies for ammonia synthesis

In late February, Yokogawa Electric Corp. (Toyko; www.yokogawa.com) announced that it has invested in and signed a memorandum on a business partnership with Tsubame BHB Co., Ltd. (Yokohama, Japan; tsubame-bhb.co.jp). Yokogawa is the latest to partner with Tsubame BHB, joining Heraeus Group, Idemitsu Kosan Co., Ltd., Inpex Corp., Nishinippon Plant Engineering and Construction Co., Ltd. and others.

Tsubame BHB is a university-based startup that was founded in 2017 by a group headed by professor emeritus Hideo Hosono of the Tokyo Institute of Technology (TiTech; Yokohama, Japan; www.msl.titech.ac.jp). Professor Hosono and colleagues first developed an ammonia synthesis method that makes use of electride catalysts (for more information about the catalyst, see *Chem. Eng.*, December 2012, p. 12).

Tsubame BHB's electride catalysts enable the synthesis of hydrogen and nitrogen at relatively low temperature and pressure levels (300–400°C, 3–5 MPa) compared to the conventional iron-based catalyst of the Haber-Bosch process (400–500°C, 10–30 MPa). The catalyst is made by attaching ruthenium atoms to nanometer-sized cages of a calcium aluminate electride, which confines electrons within the cage. The electride — $12CaO{\cdot}7Al_2O_3$ (hereafter C12A7) — is a component found in cement. Hosono's group developed the C12A7 electride system and professor Michikazu Hara's group (both at TiTech's Materials and Structures Laboratory) first applied the electride as a catalyst for NH_3 synthesis.

Since 2019, Tsubame BHB has been operating a 20-ton/yr pilot plant at the site of its major stockholder, Ajinomoto Co., Inc. in Kawasaki City. In December 2022, the company received its first commercial plant order to supply a small distributed ammonia-production plant. This first plant is scheduled to start commercial production in 2025.

lectively extract valuable metals from complex, low-concentration materials that are currently considered waste (for more details, see *Chem. Eng.,* September 2023, p. 6). This enables mining companies to reduce the financial and environmental liabilities of slag by leveraging this natural byproduct of metal production to create new revenue streams.

PEG LIPIDS

Evonik Industries AG (Essen, Germany; www.evonik.com) and the Johannes Gutenberg University Mainz (JGM; www.uni-mainz.de) have signed a license agreement to commercialize randomized polyethylene glycols (rPEGs), a new class of PEGs. Evonik intends to use rPEGs for its platform of specialized lipids and commercialize the excipients under the license agreement to meet customer and market needs. Technical grade rPEG-lipids will be available in the second half of 2024.

PEGs are polymers that have

(Continues on p. 10)

been used in the pharmaceutical industry for more than 30 years to improve the bioavailability, stability, targeting and performance of therapeutics. rPEG polymers have similar properties to PEGs but have a different structure that is intended to offer an improved immunogenicity profile. They are especially suitable for pharmaceutical applications, such as in lipids for lipid nanoparticle (LNP) carriers.

NEW MEMBRANE

Toray Industries, Inc. (Tokyo, Japan; www.toray.com) has developed an ion-conductive polymer membrane that has an ion conductivity that is 10-times higher than its predecessors. The company says the development could accelerate the deployment of solid-state batteries, air batteries and other lithium-metal batteries, while greatly expanding the cruising ranges of electric vehicles and other transportation modes.

Toray's new polymer membrane achieves an increased ion conductivity through a "hopping conduction" mechanism. This mechanism enables Li^+ ions to traverse between interacting sites within polymer membranes, effectively jumping across sites. The polymer film also functions as a protective film on Li-metal surfaces. ❒

Completely recycled viscose for the first time

Researchers at Lund University (Sweden; www.lth.se) have succeeded in converting worn-out cotton sheets into new viscose fibers using a process that — for the first time — enables all of the viscose to be recycled. Current recycling methods often require a high percentage of virgin fiber to make products from recycled textiles. As a result, old textiles are instead typically incinerated.

"Cellulose chains, the main component in plant fibers, are complex and long," explains Edvin Bågenholm-Ruuth, doctoral student in chemical engineering at Lund University. "Cotton textiles are also intensively treated with dyes, protective agents and other chemicals. And then there is all the ingrained grime in the form of skin flakes and fats," he says.

Bågenholm-Ruuth and his colleagues have developed a process, described in a recent issue of *Cellulose*, to loosen up and convert the complex cotton fibers into viscose fibers. The process uses hydrated zinc chloride ($ZnCl_2 \cdot 4H_2O$) as a solvent and swelling agent to convert waste cotton textiles into a dissolving pulp. The pulp can then be used to make viscose dope, a spinning solution that can be spun into stable viscose fibers.

The process has the advantage of using $ZnCl_2 \cdot 4H_2O$, a soluble, inexpensive salt, and requires a smaller percentage of carbon disulfide compared to standard viscose-spinning processes. The result is good-quality viscose fiber, even though the process needs to be further optimized, Bågenholm-Ruuth says. Also, an additional step may be required for recycling old clothing that has been dyed.

Startup company ShareTex AB (Bjärred, Sweden; www.sharetex.com) is working to further develop the technology. The process could be demonstrated at commercial scale within five to seven years. ■

Business News

Plant Watch

EuroChem launches phosphate-fertilizer manufacturing complex in Brazil

March 14, 2024 — EuroChem Group (Zug, Switzerland; www.eurochemgroup.com) opened a new fertilizer-production facility in Serra do Salitre, Brazil. With a total project investment of nearly $1 billion, the new phosphate mine and plant complex will have a production capacity of 1 million metric tons per year (m.t./yr) of advanced phosphate fertilizers.

Linde Engineering to supply ASU and NWU to Australia's largest urea plant

March 13, 2024 — Linde Engineering (Pullach, Germany; www.linde-engineering.com) will supply an air separation unit (ASU) and a nitrogen wash unit (NWU) for a urea plant operated by Perdaman Industries in Karratha, Western Australia. Upon completion, the urea plant will be the largest in Australia. The single-train ASU will have a capacity of 63,000 Nm^3/h of gaseous oxygen. The single-train NWU, with a capacity of 392,000 Nm^3/h of synthesis gas to supply the downstream ammonia plant, will be the world's largest single-train NWU.

Shin-Etsu to double production capacity for hypromellose acetate succinate

March 8, 2024 — Shin-Etsu Chemical Co. (Tokyo; www.shinetsu.co.jp) plans to double the manufacturing capacity of hypromellose acetate succinate, a pharmaceutical excipient product, at the company's Naoetsu plant in Japan. With completion expected in 2026, the estimated investment for the expansion project is ¥10 billion (around $67.5 million).

Zeon completes construction of new recycling plant for cyclo-olefin polymers

March 8, 2024 — Zeon Corp. (Tokyo; www.zeon.co.jp) has completed construction of a recycling plant for cyclo-olefin polymers (COP) at its Takaoka plant in Japan. The new plant will recycle waste resin that is generated when processing COP into film, using it to manufacture optical films. The plant has a processing capacity of 6,000 m.t./yr.

Mitsubishi Chemical expands production capacity for sugar-ester emulsifier

March 4, 2024 — Mitsubishi Chemical Group (MCG; Tokyo; www.mcgc.com) will expand its sugar-ester production capacity by adding a new line with a capacity of 1,100 m.t./yr at its Kyushu plant in Japan. Operation of the new production line is scheduled to start in March 2026. Sugar ester is an emulsifier used to maintain quality in food processing and storage applications. It is made primarily from sucrose and fatty acids derived from vegetable oils and fats.

Mitsui Chemicals to expand XDI production plant

February 28, 2024 — Mitsui Chemicals, Inc. (Tokyo; www.mitsuichemicals.com) will increase production capacity for *meta*-xylylene diisocyanate (XDI) plant at its Omuta plant in Japan. This expansion will raise domestic XDI production capacity by 20%. Construction on the project is slated for completion in July 2025, with startup tentatively scheduled for September 2025. XDI is a special isocyanate that Mitsui Chemicals was the first in the world to produce on a commercial scale.

AkzoNobel completes powder-coatings capacity expansion in Vietnam

March 4, 2024 — AkzoNobel N.V. (Amsterdam, the Netherlands; www.akzonobel.com) announced that a major investment project has been completed at the company's production plant in Bac Ninh, Vietnam. Five new powder-coating lines have been added at the site, along with a line for producing water-based products for the consumer electronics market. The total investment amounts to €18.5 million.

UBE to build integrated DMC/EMC plant in Louisiana

March 1, 2024 — UBE Corp. (Tokyo; www.ube.com) plans to construct a dimethyl carbonate (DMC) and ethyl methyl carbonate (EMC) plant in Louisiana capable of producing 100,000 m.t./yr of DMC and 40,000 m.t./yr of EMC. The total capital investment will be approximately $500 million, with the completion of construction scheduled for July 2026. Operations are expected to begin in November 2026. DMC and EMC are key components in electrolyte solvents for lithium-ion batteries.

Arlanxeo to construct a new HNBR plant in China

March 1, 2024 — Arlanxeo (Maastricht, the Netherlands; www.arlanxeo.com) plans to construct a new plant to produce hydrogenated nitrile butadiene rubber (HNBR) in Changzhou, China. With a nameplate production capacity of 5,000 m.t./yr, the first phase of construction will enable the production of 2,500 m.t./yr of rubber. The plant is expected to begin operations in the third quarter of 2025.

AkzoNobel opens new paints and coatings plant in Pakistan

March 1, 2024 — AkzoNobel has opened a new €26-million manufacturing plant in Faisalabad — the company's largest investment in Pakistan to date. The new site has facilities for making decorative paint, wood finishes, automotive and specialty coatings, coil coatings and protective coatings to help meet increasing demand across a variety of markets.

LINEUP

Look for more latest news on chemengonline.com

Cepsa and Bio-Oils to construct world-scale biofuels plant in Spain

February 28, 2024 — Cepsa (Madrid, Spain; www.cepsa.com) and Bio-Oils are beginning construction of the largest second-generation biofuels plant in southern Europe. This facility will produce 500,000 m.t./yr of sustainable aviation fuel (SAF) and renewable diesel. The new plant, along with the existing facilities operated by Cepsa and Bio-Oils in Huelva, Spain, will form the second-largest renewable-fuels complex in Europe, with a total production capacity of 1 million m.t./yr. The new facility's startup is planned for 2026, following a €1.2-billion investment.

Röhm commissions expanded Plexiglas plant in Germany

February 22, 2024 — Röhm GmbH (Darmstadt, Germany; www.roehm.com) has expanded production capacity for polymethyl methacrylate (PMMA; tradename Plexiglas) molding compounds at its site in Worms. Work began on the expansion in 2022, and commissioning was completed in early 2024.

Mergers & Acquisitions

Trinseo commences plans to sell 50% stake in AmSty joint venture

March 14, 2024 — Trinseo (Berwyn, Pa.; www.trinseo.com) has commenced a sale process for its 50% ownership in Americas Styrenics LLC (AmSty), a joint venture (JV) with Chevron Phillips Chemical Co. LP (CPChem; The Woodlands, Tex.; www.cpchem.com). Trinseo expects the exit process to lead to a definitive arrangement no later than early 2025.

Solvay and Carester enter MOU related to rare-earth magnets

March 11, 2024 — Solvay S.A. (Brussels, Belgium; www.solvay.com) and Carester (Lyon, France; www.carester.fr) signed a memorandum of understanding (MOU) to form a strategic partnership related to the value chain for rare-earth magnets. In the partnership, Solvay is contributing its industrial assets and operational experience, and Carester is bringing expertise in recycling end-of-life equipment, upstream market knowledge and related activities.

Evonik sells superabsorbents business to ICIG

March 4, 2024 — Evonik Industries AG (Essen, Germany; www.evonik.com) is selling its superabsorbents business to the International Chemical Investors Group (ICIG; Frankfurt am Main, Germany). The final transfer of the business is planned for mid-2024 following approval by the relevant competition authorities.

LyondellBasell acquires plastics-recycling assets in California

February 20, 2024 — LyondellBasell Industries N.V. (LYB; Rotterdam, the Netherlands; www.lyondellbasell.com) acquired plastics-recycling assets from PreZero. The transaction includes leasing the PreZero processing facility in Jurupa Valley, Calif., which has a production capacity of 23,000 m.t./yr for recycled materials. LYB plans to use this mechanical recycling plant to manufacture post-consumer recycled resins using plastic-waste feedstock. LYB expects to commence operations at the facility in 2025. ■

Mary Page Bailey

Innovations in Seals and Gaskets Boost Reliability

New designs and materials overcome high temperatures, pressures and aggressive media

In the chemical process industries (CPI), standard equipment is often capable of working universally across many applications. However, this same notion does not apply to the sealing elements used in chemical processes, where it is imperative that seals and gaskets not only suit the application, but can also safely handle any environmental variables, such as aggressive media, high temperatures and pressures and cleaning regimes. Fortunately, advanced seals and gaskets are being developed that overcome CPI challenges to ensure a proper seal that encourages the highest reliability in a variety of traditional and emerging applications.

"Each industry faces its own inherent challenges specific to its processes, but the overarching challenge across all industries and applications is to increase the plant's overall reliability," says Alan Evans, global director, product line management for the mechanical seal business with A.W. Chesterton (Groveland, Mass.; www.chesterton.com). "Reliability touches on sealing concerns, such as aggressive temperatures; high pressures and temperatures; emissions; and health and safety and impacts the financial performance of the plant. Sealing challenges are tied into plant reliability, but it isn't until there is a good understanding of what causes failure that you can begin to mitigate these challenges."

Enhanced reliability

The best way to understand and address these challenges is by realizing that seals and gaskets are part of the overall system in which they are contained, continues Evans. "Nothing operates in isolation," he says. For this reason, sealing device designers and manufacturers are striving for a better understanding of the factors that contribute to failure and are trying to mitigate the impact on the sealing device itself to provide better operating life and reliability.

"Part of our engineering team's philosophy is to design for reliability," notes Evans. He explains that there are five key features that help mechanical seals operate more reliably and that Chesterton is building these features into new sealing products, as follows:

- Protected springs to maintain free motion within the seal between the rotary and stationary seal faces
- Balanced design to decrease the amount of pressure applied to the seal faces from the sealed fluid to reduce heat generation, minimize distortion and increase the operating envelope of the seal
- Non-fretting design so the machine or internal metal components of the seal are not damaged in a way that interrupts the seal's operating capabilities and to improve the ability of users to replace wearable parts and return the seal to operation versus having to purchase a new seal
- Monolithic seal faces so the seal face is composed of one homogeneous material to reduce the effects of temperature distortion, which will limit the seal's performance concerning leakage and lower emissions performance
- Stationary design so the seal only makes one adjustment to misalignments that are inherent to all rotating equipment

Recently, Chesterton released a line of high-performance seals that incorporate these features. Chesterton's 1810 (Figure 1) is a scalable mechanical sealing solution that can be used in a variety of pumps to provide a reliable and economical sealing solution. The 1810 mechanical seal can be configured with several different face profiles and auxiliary components for demanding applications. For example, a hydropad face option can be applied for use in hot process media or a line-to-line face option may provide greater sealing security in chemical slurries. Meanwhile, the 2810 is a double seal with advanced features that provide superior emissions control, safety and reliability. Suitable for sealing hazardous or dangerous process fluids, the 2810 offers a patented diffuser sleeve that increases buffer/barrier fluid flowrates and disperses the cool fluid directly at the seal face interfaces, collecting and removing the hotter fluid and transporting it back to the seal tank system.

Another development aimed at providing a tighter and more reliable seal is the ability to accommodate more complex geometries, says Tom Rimel, president at Stockwell Elastomerics (Philadelphia, Pa.; www.stockwell.com). "Traditionally, O-rings and circular shapes were the common offerings, but there are often intricate patterns that require cutting materials or using multiple seals or gaskets around a compli-

A.W. Chesterton

FIGURE 1. Chesterton's 1810 mechanical seal can be configured with several different face profiles and auxiliary components for demanding applications, while the 2810 is a double seal with advanced features that provide superior emissions control, safety and reliability

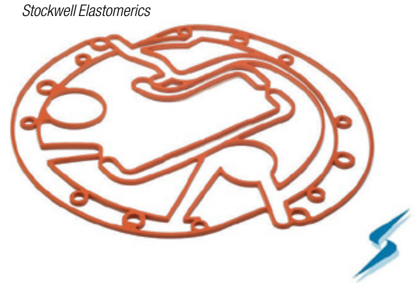


FIGURE 2. The ability of Stockwell to create more complex geometries using waterjet cutting, CNC flash cutting and a variety of 3-D molding capabilities provides seals and gaskets in more intricate shapes and provide a better seal without using multiple gaskets

cated shape," explains Rimel. "But recently we've been able to provide more complex geometries using waterjet cutting, CNC flash cutting and a variety of 3-D molding capabilities [Figure 2]. This allows us to provide seals and gaskets in more intricate shapes for applications in controls equipment, valve actuators and sensors, and provide a better seal around a complicated shape without using multiple gaskets. Because the ability to provide complex geometries enables a tight seal using a continuous piece of material versus multiple gaskets, which tend to leave a seam and reduce the reliability of the seal, it is a game changer in many applications."

Innovations meet challenges

While seals can be designed to provide higher levels of reliability, it is sometimes still a challenge to find a seal that not only meets the needs of the application but also the demands of the environment in which it will operate, says Oliver Cann, product and engineering director with Vulcan Seals (Sheffield, UK; www.vulcanseals.com). "A lot of processors specify seals to suit the direct application with which they are working, but there are a lot of other variables to consider," he says. "It is possible that the material that is ideal for the media doesn't jive with the temperatures, pressures or cleaning process, which can make it difficult to effectively specify a commercially viable or commercially reasonable sealing technology that covers all the application parameters."

As a solution, Vulcan Seals offers encapsulated seals in a variety of materials. "Our FEP- (fluorinated ethylene propylene) and PFA- (perfluoroalkoxy alkane) encapsulated seals [Figure 3] are resistant to a wide range of chemicals and serve as a universal O-ring that can work in a variety of applications," notes Cann. Vulcan's encapsulated seal products are O-rings that are bound by a seamless and uniform FEP/PFA encapsulation, which encloses an elastomeric core, completely protecting it from the media. They combine the energizing properties of an elastomeric O-ring with the resilience to extreme temperature and hostile chemicals provided by FEP/PFA.

"The rubber creates a unique energy whereby under compression it creates load, which is essential for creating a pressure-tight seal that is able to block a barrier while also allowing the use of a highly inert and chemically resistant material as the contact barrier," explains Cann. "Traditionally a PTFE (polytetrafluoroethylene) would be the commercially viable seal material used in difficult applications, but it doesn't provide the energy that is achieved via the rubber elastomer core. Here, we get the energy needed from the rubber elastomer, but protect it with a highly resistant barrier and use a process to make the encapsulation around them seamless to provide a leak-tight seal that resists damage from chemicals and other process variables that are common in the chemical industry."

Another sealing challenge in the CPI is the requirement for cleaning-in-place (CIP) and sterilization-in-place (SIP) regimes. Often, seals that suit the other aspects of the application cannot withstand the demands of these processes, making it difficult to find a reliable seal, especially in food-and-beverage applications.

"The sealing environment for food-and-beverage processing is one of the most demanding," says David Kaley, global segment manager with Trelleborg Sealing Solutions (Trelleborg, Sweden; www.trelleborg.com). "Seals are essential to food safety, ensuring that contaminants do not come in contact with the food. Seal failure can lead to potential contamination, resulting in line stoppages, recalls or, in the worst case, harm to consumers. Materials, whether elastomer or plastic, must cope with the processing of a broad variety of food types along with CIP and SIP regimes, which can quickly destroy incorrectly specified seals. On top of this, seals must comply with various global food contact regulations."

To provide sealing solutions that meet the needs of food-and-beverage processors, Trelleborg offers a family of EPDM (ethylene propylene diene monomer) rubber materials, specifically designed to meet the unique requirements of the food-and-beverage industry. Called the FoodPro EPDMs [Figure 4], the seals comply with the most comprehensive global food contact material regulations, are suitable for use with virtually all food and beverage products and can withstand harsh CIP and SIP processes. They are compression and injection moldable, which means they can be used for O-rings, static seals and engineered molded parts, and they offer dynamic properties with improved tensile strength, reduced elongation and tear and wear resistance.

'Green' energy applications

Innovation and developments in sealing technologies come at a time when they are needed in new applications surrounding the burgeoning green energy market.

"Sealing technologies help simplify energy transition for process industries," says Leo Konradsson, global segment manager, power

FIGURE 3. Vulcan's encapsulated seal products are O-rings that are bound by a seamless and uniform FEP/PFA encapsulation, which encloses an elastomeric core, completely protecting it from the media. They combine the energizing properties of an elastomeric O-ring with the resilience to extreme temperature and hostile chemicals provided by FEP/PFA

FIGURE 4. Trelleborg's FoodPro EPDM seals comply with the most comprehensive global food-contact-material regulations, are suitable for use with virtually all food-and-beverage products and can withstand harsh CIP and SIP processes

and process industries, with Roxtec International AB (Karlskrona, Sweden; www.roxtec.com). "Oil-and-gas companies are making moves to upgrade their operations to reduce their carbon footprint and, for many energy providers, energy transition is moving higher on the agenda every year. When adding units for hydrogen, carbon capture and biofuels, they need safety and quality, as well as sealing expertise within these energy transition projects. And while sealing products may be small components in large capital projects, they play an important role in safety and serve as important solutions for any operation that handles explosive and flammable gases."

Further, for decarbonization projects, seals are used in hydrocracking units, electrolyzers and biofuel plants handling renewable natural gas (RNG), steam methane reforming is) and dairy manure, as well as in e-fuel production facilities and carbon-capture units. They secure green-hydrogen-generation plants attached to ammonia and fertilizer plants. "In these applications, Roxtec seals are installed around cables and pipes in buildings, containers and cabinets and provide approved solutions for hazardous locations," says Konradsson. "As with any hazardous industry, the main concern and top priority is safety and reliable operation. The risks of production disruptions, severe accidents and worst-case loss of life must be minimized and avoided. This is done by using seals that prevent potentially explosive gases from entering cabinets and equipment in ATEX-classified areas, as well as by protecting buildings from fire and ingress of water."

In answer, Roxtec provides HD EX transit solutions (Figure 5). "HD stands for high density and refers to the high number of cables that can be safely routed through a minimum area of a cabinet," explains Konradsson. "This migration from traditional cable glands has resulted in smaller and lighter cabinets, which saves money, time and space in projects. These seals also allow for late cable changes and modifications without having to do drilling or welding on site. Users simply open the seal, route the new cable through and use the compression unit to seal the opening again. Roxtec seals can be used with both standard and armored cables. The BG (bonding and grounding) modules come fitted with an integrated copper braid, which bonds the armor in accordance with Underwriters Laboratories Standard UL 514B.

FIGURE 5. Roxtec HD EX transit solutions allow smaller and lighter cabinets, saving money, time and space in energy transition projects in CPI. These seals also allow for late cable changes and modifications without having to do drilling or welding on site

Also realizing the need to create seals that are compatible with the green-energy movement, Chesterton has a dedicated research and engineering team that works on designs to meet the specific requirements of these types of applications. "For example, we have designed and implemented a gas-operated seal for a new green-energy technology that extracts energy from a plant's waste-steam streams," says Evans. "This energy is then put back into the plant's electrical system for reuse, both saving the plant money and reducing their waste energy stream for greater sustainability and reduction of their carbon footprint."

And, the fuel-cell market is also necessitating the use of novel sealing technologies, as well, says Stockwell's Rimel. For example, fuel cells, which are a growing technology in decarbonization efforts as they are devices that generate electricity through an electrochemical reaction rather than combustion, require gaskets that offer temperature resistance, strength and inertness, says Rimel. Stockwell offers platinum-cured silicone rubber that can be molded into flat, window gasket configurations or made with added sealing beads for these applications. Fuel-cell gaskets of this material can be die cut, water-jet cut or molded to custom geometries as needed and offer improved compression set properties. "The improved compression set, along with the purity of the platinum-cure silicone have found favor with the fuel cell industry," he says.

Similarly, he says, electric vehicle (EV) batteries require a lot of seals, because most of the structures have multiple layers of materials that must be built into a self-contained unit. "EV batteries can have issues with heat buildup and, if there is too much heat, it can degrade the battery and shorten its lifespan, or worse, generate fire that must be prevented from spreading," he explains. "There are opportunities there for elastomers, membranes and other materials that deliver specified performance. The seals and gaskets in these applications must have different fire ratings and temperature ranges than traditional automobile seals and gaskets."

He continues: "As we continue to see more green and sustainable technologies, there will be a call to provide different seal and gasket materials and technologies to match the needs of these niche applications." ■

Joy LePree

Focus on Valves

Ensure plant safety with this aseptic valve technology

This company now equips the aseptic double-seat valves of the Aseptomag range with lockout-tagout (LoTo) devices. LoTo devices are mechanical locking systems that isolate machinery from potentially hazardous energy sources prior to maintenance or servicing activities. Because the Aseptomag double-chamber valves act as transfer points between process steps, they can be used to control the plant's energy supply and secure it very effectively with LoTo. The Aseptomag DK valves (photo) are equipped with a modified valve actuator that includes a special lantern and piston-rod extension for the socket pin. To safely lock the valve, the operator inserts the socket pin into the lantern opening until the metallic stop is reached. This disk-lock principle prevents any movement of the actuator and valve disk. — *GEA AG, Düsseldorf, Germany*
www.gea.com

Position transmitter for critical isolation-valve applications

The HART-enabled Fieldview 4400 valve-position transmitter (photo) is very easy to calibrate, and it incorporates a proven, linkage-less design. As compared to limit switches, it provides much higher reliability, along with valve diagnostics and safety-integrity-level (SIL)-2 capabilities. The position transmitter also includes limit switch outputs, so it can be retrofitted into an existing on/off switch circuit, while also taking advantage of the valve position information. — *Emerson, Marshalltown, Iowa*
www.emerson.com

Pneumatic quarter-turn actuators for process control

The double- and single-acting pneumatic actuators of the Actair EVO and Dynactair EVO type series (photo) are designed for actuating all types of partial-turn valves, such as butterfly valves, ball valves and plug valves. The double-piston actuators can be operated with compressed air to ISO 8573-1 from 3 to 8 bars. The maximum torque is 8,000 Nm for the double-acting type and 4,000 Nm for the single-acting variant. The maximum ambient temperatures should be between –50 and 150°C. With their IP68 enclosure, the actuators are suitable for use in a maritime environment. This means that, in the event of flooding, they will remain water-tight for about 169 h at a depth of up to 30 m. As standard, the actuator is fitted with a position indicator and adjustable mechanical stops. With their standardized interfaces, the actuators can be connected to higher-level process control systems with solenoid valves, positioners and diverse digital and analog control units. — *KSB SE & Co. KGaA, Frankenthal, Germany*
www.ksb.com

This rotary valve is designed for easy cleaning

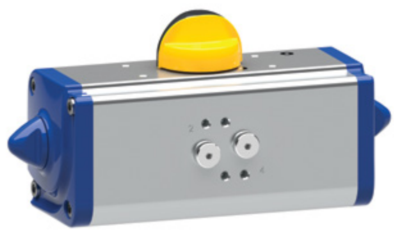
The ZXD rotary valve (photo) is made from stainless steel, which is resistant to corrosion and suitable for sanitary applications. The ZXD includes a patented blow-through channel for optimal pocket sweeping and offers pressure differentials up to 1.5 bars(g). Standard operating temperatures are up to 100°C and special configurations are available for higher temperature to 150–220°C. Heavy Duty design includes an explosion pressure shock-proof rating of 10 bars(g). The valve is available with standard totally-enclosed fan-cooled (TEFC) motor, washdown, and IEEE Severe Duty gear motors. — *Coperion K-Tron Salinas, Inc., Salinas, Kan.*
www.coperion.com

A new quarter-turn, smart electric actuator

The new Limitorque QX Series B (QXb) electric actuator provides unmatched reliability and precision, while lowering the cost of ownership in a range of demanding applications, according to this company. The QXb actuator enables backward compatibility with older QX actuators, via a conversion kit, which helps reduce costs and provides future-proofing. The QXb actuator (photo, p. 18) is engineered to maximize dependability and efficiency while while supporting decarbonization initiatives. A large, high-resolution


GEA


Emerson


KSB


Coperion K-Tron

Flowserve

Schubert & Salzer Control Systems

liquid crystal display (LCD) with adaptive brightness control provides improved legibility, as well as real-time actuator status and valve position. Its IP68-rated, double-sealed enclosure and non-intrusive control knobs eliminate the risk of water or dust ingress for improved reliability. This design also removes the need for a heater. Increased precision is also achieved with 0.1% positioning accuracy. — *Flowserve Corp., Dallas, Tex.*
www.flowserve.com

New angle seat valves for hygienic production

This company is extending its range of sterile and aseptic valves with two new types of hygienic angle seat valves. The shut-off valve type 7015 and the control valve type 7025 with integrated digital positioner (photo) are specially adapted for use in the production of food and beverages. These valves are used, among other things, to control and shut off product streams, drinking water, CO_2 and nitrogen, as well as sterile steam and sterile air. All wetted stainless-steel surfaces of the dead-space-optimized valve construction can be manufactured with a surface roughness of less than Ra 0.8 µm. The new valve types in the nominal sizes DN 15–50 and the pressure class PN 40 are suitable for media with temperatures from –30 to 170°C and in special versions from –50 to 180°C. All wetted plastics are FDA-compliant and conform to the EC Regulation 1935/2004, as well as the EU Plastic Regulation 10/2011. — *Schubert & Salzer Control Systems GmbH, Ingolstadt, Germany*
controlsystems.schubert-salzer.com

This new manual ball valve limit switch is corrosion resistant

The new J-Switch manual limit switch (photo) is compatible with this company's Type-21/21a ball valves and Type-23 Multiport ball valves. The new limit switch is a low-cost, manual valve position-indication solution. Available in 0.5-, 0.75-, 1.0-, 1.5- and 2.0-in. sizes, the J-Switch features a compact profile, direct-mount, glass-filled polypropylene enclosure that requires no tools for simple field instal-

Asahi/America

lation. The J-Switch also features 0–180 a.c./d.c. multi-voltage capabilities, a corrosion-resistant, NEMA 4X enclosure and a cable gland with 2-m flying leads. It operates at temperatures up to 150°F. — *Asahi/ America, Inc., Lawrence, Mass.*
www.asahi-america.com

Improved two-stage actuator for diaphragm valves


GEMÜ Gebr. Müller Apparatebau

The revised 9658 two-stage actuator (photo) has smaller dimensions and is 25% lighter than its predecessor. It is also easier to clean since the actuator housing is now welded. For diaphragm valves with two-stage actuators, a continuous series of nominal size DN 10 to DN 65 (diaphragm size 10 to 50) is available. These pneumatically operated two-stage actuators feature a stainless-steel actuator housing, along with two pistons that operate independently of one another and can be actuated separately. They can perform either a full stroke or a variably adjustable partial stroke. This makes these two-stage actuators suitable for filling applications that require rapid open/close cycles and precise metering. — *GEMÜ Gebr. Müller Apparatebau GmbH & Co. KG, Ingelfingen-Criesbach, Germany*
www.gemu-group.com

Lug-style butterfly valve is corrosion-resistant

The Type 565 lug-style butterfly valve (photo) completes this company's Type 565 portfolio of lightweight, corrosion-free options for water-transport and water-treatment applications. The lug-style design is highly suitable for use as an end valve, permitting one-sided disassembly. Like the Type 565 Wafer, the Type 565 Lug is designed to directly compete with metal valves. Offering corrosion and abrasion resistance while being lighter than metal equivalents, both the 565 Wafer and 565 Lug exist as cost-effective alternatives. Compatibility with the company's other automation components allows for seamless integration into an automation loop. Furthermore, the valves carry an Environmental Product Declaration (EPD), as well as numerous marine and water approvals. — *GF Piping Systems, Irvine, Calif.*
www.gfps.com

GF Piping Systems


Gerald Ondrey

Continuous Tubular Reactors with Static Mixing Elements

Department Editor: Scott Jenkins

Batch manufacturing methods are common throughout the chemical process industries (CPI) for specialized compounds and reactions. However, typical batch-wise manufacturing processes are often time-consuming due to large volumes and long loading and unloading times added to the batch processing time, which can cause delays between batches. Continuous reactors, such as tubular reactors (plug-flow reactors), continuous stirred-tank reactors (CSTRs) and modular configured microreactors, can help processors realize a host of efficiency and productivity benefits over batch processes, including improved control over reaction conditions, more consistent product quality and opportunities for larger product output with a smaller footprint (Figure 1) [*1*]. In particular, thoughtfully constructed tubular reactors with static mixers can have positive implications for sustainability, safety, process intensification and product quality.

Tubular reactor advantages

Tubular reactors containing static mixing elements can achieve thorough mixing with precise control over residence time and can tighten residence-time distributions in continuous reactions. This type of tubular reactor allows improved control over reaction conditions and temperature, while still maintaining excellent heat and mass transfer. Compared to empty tube reactors, tubular reactors with static mixers have advantages with respect to product yield and selectivity, as well as improved heat transfer (Figure 2).

The mixing elements inside the reactor tube continuously split and recombine the fluid streams, and help homogenize concentrations and temperatures across the pipe cross-section. This leads to a more homogeneous residence-time distribution, less reactor wall effects and minimized stagnant boundary layers. Overall, tubular reactors with static mixers promote optimal renewal of the concentration and temperature next to the reactor wall, with positive effects on product quality.

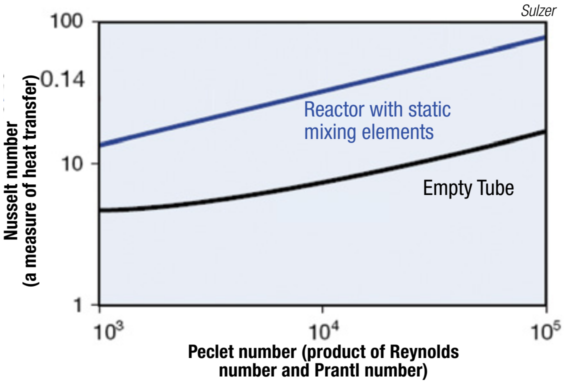


FIGURE 2. Reactors with static mixers have improved temperature profile compared to empty tubes

In an example of the potential impact of mixing elements, a leading pharmaceutical company saved $9 million/yr via improved product yields by changing from an empty tube reactor to a tube reactor with static mixing elements.

Safety

Tubular reactors containing static mixers provide superior safety control through better product consistency and the avoidance of adverse reactions. Smaller reaction volumes at any given time minimize the dangers associated with hazardous or exothermic reactions. Monitoring the process with sensors, such as temperature or pressure probes, allow for constant process-parameter monitoring and real-time quality control.

Scale up

Although continuous reactors can have real benefits, process adaptation is a critical aspect in transitioning from batch processes to continuous ones. Several factors, such as reaction rate, reaction kinetics, rate constant and order of reaction, play a vital role in determining ideal reactor sizes and operating conditions. Reliable scale up — possibly in steps — and ongoing process optimization during the transition, including small-scale testing before growing to industrial-scale production, allow a high degree of success in the changeover.

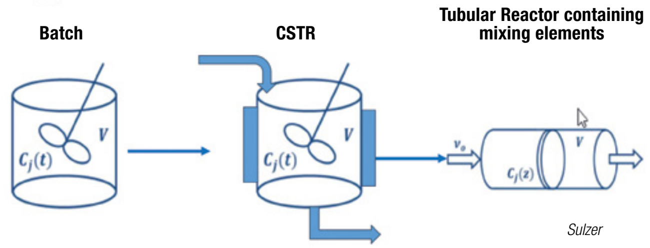


FIGURE 1. Continuous processes, such as those using a CSTR or tubular reactor, have advantages over batch processes

Test skids or components are available for rent to conduct such tests in users' own laboratories. With the data collected, scaleup can be carried out using internal calculation tools and scaleup rules backed up by computational fluid dynamics (CFD) simulations. Normally, the test size is around 1–6 L/h [*2*]. Therefore, a kilogram-scale laboratory test after the initial studies would make sense in general. During the scale-up procedure, attention should be paid to heat development during the reaction. Especially in larger pipe diameters, the available exchange surface and heat increase must be kept in mind.

Also, because of the static nature of the mixing, complications like fouling — especially when solid catalysts are present or precipitation takes place — or clogging need to be considered in more detail. ■

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Editor's note: The content for this column was assembled by Dr. Kishor Kulkarni, sales and application manager for mixers at Sulzer Chemtech Ltd. (Winterthur, Switzerland; www.sulzer.com), and Marcel Suhner, global product and application manager for mixers at Sulzer Chemtech.

New Products

This range of high-performance water pumps expanded

This company has expanded its RDLO series from 21 sizes to 33 (photo). The pump sets are axially split volute casing pumps primarily used for clean water transport. A casing with double-volute compensating radial forces and a double-entry impeller compensating axial forces are key to a long service life. As a result, the generously dimensioned rolling-element bearings are subjected to a minimum load only. Thanks to the expansion of the series, flowrates of up to 20,000 m³/h at heads of up to 300 m can now be achieved. Because RDLO pumps are also capable of transporting seawater, the materials used include duplex steels alongside standard materials, such as gray cast iron and nodular cast iron. — *KSB SE & Co. KGaA, Frankenthal, Germany*
www.ksb.com

KSB

Explosion-proof conveyors for combustible dusts

The VS pneumatic vacuum-conveying system (photo) features an explosion-proof design that will aid in compliance with the NFPA 660 Standard for Combustible Dusts and Particulate Solids, which aims to consolidate NFPA 61, 484, 652, 654, 655 and 664 into a single standard. Eliminating electrostatic charges as a potential ignition source, the vacuum conveyors automatically transfer ignitable powders in a sealed system without electricity. The conductive design safely dissipates any static charge. Pneumatically driven, non-rotating parts eliminate heat generation as a source of ignition and the enclosed system prevents nuisance dust from accumulating as a fuel source. — *Volkmann USA, Bristol, Pa.*
www.volkmannusa.com

Volkmann USA

This temperature transmitter has Ethernet-APL

The new iTEMP TMT86 two-channel temperature head transmitter (photo) has Profinet communication over Ethernet Advanced Physical Layer (APL). The two-channel temperature head transmitter is suitable for use with resistance thermometers and thermocouples and provides fast and accurate measurement of temperature. The device supports a wide range of thermocouple elements and resistance temperature detectors (RTDs). The iTEMP TMT86 also has a built-in web server that allows users to operate the instrument from any computer or mobile device and supports easy configuration as well as monitoring of processes without the need for additional software or hardware. — *Endress+Hauser AG, Reinach BL, Switzerland*
www.endress.com

Endress+Hauser

Technological leap for the new-food industry

At the Anuga FoodTec trade show (Cologne, Germany; March 19–22, 2024), this company's new-food experts discussed their perfusion platform — a key technology for state-of-the-art upstream bioprocesses that also enables continuous processing in cell cultivation and precision fermentation. In this process, cells from the Axenic bioreactor are separated from the nutrient solution containing inhibitors using the kytero single-use separator (photo) to improve the density of living cells and boost productivity. This technology offers great potential for the reprocessing of media, which represents a considerable cost factor in new-food production and hence in the end products. — *GEA Group, Düsseldorf, Germany*
www.gea.com

GEA

A level sensor with IO Link technology

This company's KA1590 capacitive sensor (from the 26 Series) now has IO Link Technology. This IO Link sensor (photo) can detect products with a low 1.1 dielectric. The sensor comes with normally open contact and normally closed contact. ON and OFF delay timing functions are programmable for the application requirements. The sensor operates on 10–35 V d.c., the housing is IP67 sealed for cleaning in place (CIP) and installation is quick with tri-clamp mounting. The sensor's PTFE housing is FDA 21 CFR 177.1550 compliant for use in food and pharmaceutical applications. The sensor has a temperature rating up to 100°C. — *Rechner Electronics Ind. Inc., Sanborn, N.Y.*
www.rechner.com ■

Rechner Electronics Ind.

Gerald Ondrey

Selecting Industrial Gas Suppliers: Consider Integration Synergies

Engineering teams at operating companies can help maximize the value of industrial gas supplies by optimizing the requirements of the gas supplier with the chemical producer

John Peterson
Industrial Gas Commercial Advisors LLC

IN BRIEF

OPTIIMIZATION CONSIDERATIONS

AREAS OF POTENTIAL INTEGRATION

QUESTIONS FOR DISCUSSION

The industrial gas (IG) industry has been around for decades, with some IG suppliers tracing their histories for well over a century. And although the industry continually evaluates and implements new technologies, most IG production processes are quite mature. For example, cryogenic distillation, a process that traces its origins back to the late 1800s, is typically still the preferred technology to produce large volumes of gases like oxygen and nitrogen (Figure 1).

For the grassroots chemical-process-industries (CPI) manufacturer needing world-scale volumes of industrial gas, the IG suppliers will typically propose a production facility to be built on or adjacent to the consumer's plant (generally referred to as an "on-site" plant). In some areas, such as the U.S. Gulf Coast, existing IG pipeline enclaves may be available for tie-in, which gives the IG producer flexibility in determining the most cost-effective size and location for the addition of IG capacity along the pipeline.

Since the number of IG suppliers offering on-site solutions is relatively limited (the industry is frequently referred to as an oligopoly) and given the maturity of IG production technology, one would expect a relatively straightforward procurement process for the selection of an industrial gas supplier. Many CPI operating companies use a traditional RFP (request for proposal) for industrial gas supplies, which need only define their gas demands in terms of the technical requirements (such as quantity required, flow profiles, purities, and pressures) and commercial terms (such as contract duration, contingency protocols and pricing specification).

It is not uncommon for such RFP procedures to generate bid results that are extremely close. This is not surprising, since IG suppliers offering on-site solutions tend to use many of the same major equipment suppliers and tend to require similar returns on their capital investments. Bid differentials of 1–2% are not unusual between the top two IG bidders for an on-site opportunity.

In the experience of the author, the RFP process, however, does not typically capture integration synergies that generate significant operational expenses (OpEx) savings (primarily power) and capital expenses (CapEx) optimization between the requirements of the consumer and the IG supplier. Such synergies can generate savings far more significant than those evident from the bid results of the RFP. On the OpEx side alone, for ex-

FIGURE 1. Cryogenic distillation in air-separation units (ASUs), like the one shown here, is a widely used technology to generate large volumes of oxygen and nitrogen

ample, cost savings of greater than 15% are possible and should be reflected directly in the consumer's price for the industrial gas or gases needed.

The purpose of this article is to suggest a somewhat expanded IG supplier-selection approach to capture such savings. The process requires both the IG users' commercial and technical teams (composed primarily of process engineering and project management personnel). Such teams at chemical production facilities work with the IG suppliers to maximize their value proposition from the IG bidders (in terms of optimizing the tradeoffs between OpEx, CapEx, flexibility and gas availability). This selection approach supplements the initial RFP, and is similar in many ways to negotiated procurement. It requires significant dialogue between the IG supplier and IG consumer facility, and is generally more successful if the personnel at the consumer facility has a general understanding of the business drivers influencing the IG bidders, including their market position, their contracting preferences, and areas of potential integration between the consumer's and the IG supplier's production processes. These topics are highlighted below.

Optimization considerations

It is recognized that commercial and technical resource constraints and project scheduling pressures prevent the typical operating company from following a negotiated procurement approach with many IG suppliers. For this reason, it is suggested to use the RFP process to shortlist potential IG suppliers, then work with two suppliers to evaluate the synergies discussed here before selecting the successful bidder.

One word of caution here — admittedly, this suggested approach does not work unless the finalist IG suppliers feel they can share their ideas confidentially. The operating company must reinforce this requirement with its commercial and technical teams to avoid even the perception that good ideas are being "shopped."

For purposes of illustration, assume the CPI consumer needs large volumes of gaseous oxygen. This would be typical for products such as ethylene oxide (EO), which routinely consume over 1,500 STPD (short tons per day) of oxygen as feedstock. As such, it represents an oxygen load that is attractive to most IG suppliers. This quantity of oxygen would justify the process and commercial integration techniques set forth in this article. To a lesser extent, the same optimization considerations apply for the procurement of other on-site gases, such as hydrogen and carbon monoxide, but because of byproduct considerations and cryogenic liquid backup capabilities associated with a cryogenic distillation air separation unit (ASU), the integration opportunities are easier to illustrate using oxygen as an example.

Before proceeding, it is important for the CPI operating company to understand that the value of the business may be viewed quite differently by the potential bidders. And, to a certain extent, the IG user can impact this value. The goal is to maximize the attractiveness of the user's "baseload" oxygen demand in the context of the IG supplier's strategic objectives in the geography. If the IG supplier spends incremental CapEx for its needs in the market, the potential exists for the gas consumer's "baseload" pricing to benefit based upon how the capital Is allocated. This typically involves the IG supplier adding merchant liquid addition for sale to third parties, and is discussed further in the next section below.

It is also relevant to discuss the commercial structure in which IG suppliers sell their products. This primarily falls into one of two categories: SOE (sale of equipment) or SOG (sale of gas). In the SOE case, the consumer essentially purchases the IG production equipment or the turn-key IG facility. The consumer facility may operate and maintain the IG facility itself or subcontract to a third party for such services. The SOG case involves buying the oxygen and related gases "over the fence". Here, the IG supplier and consumer enter into a long-term product-supply agreement (typically 15 to 20 years in duration) with agreed-upon pricing, price escalation and minimum gas-purchase obligations. The IG supplier's intent is to capture the plant investment over the agreement term at an acceptable rate of return. Those in the industry sometimes refer to sale of equipment as "buying the cow" versus sale of gas as "buying the milk".

Traditionally, the IG industry strongly prefers SOG over SOE and for the purposes of this article, a SOG model is the assumed contract structure.

Areas of potential integration

Given the preceding background, the evaluation of three areas of potential process and commercial integration is suggested. Much of this falls within the IG supplier's analysis, but it is important for the consumer to understand what the supplier is contemplating because it impacts the integration opportunities the parties should explore.

Merchant liquid synergies. If an IG supplier is considering the construction of an on-site ASU for a major oxygen requirement, it is almost a certainty that the addition of merchant products will be considered ("merchant" refers to liquified products trucked and sold by the IG supplier to third parties). The incremental addition of liquid nitrogen (LIN), liquid oxygen (LOX) and liquid argon (LAR) to an on-site facility is almost always more cost effective than the IG supplier's alternative of a stand-alone merchant plant, even if significant trucking of the merchant products is required from the new on-site facility (Figure 2). Depending upon the merchant pricing in the geography under consideration, merchant credits for sales to third parties can approach or exceed the margin of the consumer's underlying baseload requirement. In short, adding merchant capabilities can support a significant amount of incremental CapEx and allow the IG supplier to subsidize the pricing of the consumer's baseload. Essentially, it gives the IG supplier another lever to improve their bid to the consumer while maintaining their required return criteria for the ASU investment.

Given the economic benefits of adding LOX, LIN and LAR capabilities to an on-site plant, it is helpful for the consumer to have a general knowledge of each IG bidder's merchant position within the geography. If Supplier A has a dominant merchant position, while Supplier B is

FIGURE 2. Merchant products are liquefied gases that are trucked and sold by industrial gas suppliers to third parties

attempting to establish merchant capabilities, a dynamic may be established in which the bidders are looking at defensive drivers, as well as growth drivers, in terms of their aggressiveness in pursuing the consumer's baseload.

Since the IG industry uses a product line (or standardized plant) approach for most ASU plant sizes to minimize upfront engineering and execution costs (including the design of large ASU plants in this size range), the addition of merchant products can also lead to the selection of a more cost-effective plant in the product line, or better utilization of the facility appropriate for the consumer's baseload. Additionally, synergies are likely with respect to the ASU's liquid backup system if the IG supplier elects to supply merchant customers from the on-site plant. This synergy is discussed further below.

Electricity cost transparency and synergies. In addition to being CapEx-intensive, the IG production process requires significant quantities of energy. Electricity is typically the key operating cost in the case of atmospheric gases, and natural gas is typically the key operating cost with respect to process gases, such as hydrogen. Typically, the most important lever in reducing the ASU's OpEx is directly related to the power procurement strategy, so we will focus on this topic. But again, to understand the opportunities here, it is beneficial to understand some of the behaviors and standard practices of the IG industry.

As noted above, the sale-of-gas model is by far the IG industries' preferred method of supply. When promoting SOG, IG suppliers will frequently (and appropriately) claim that the consumer essentially has a power performance guarantee over the entire life of the contract, as opposed to an initial (or limited) performance test guarantees associated with the sale-of-equipment model.

In the SOG model, each product's price typically has a coverage factor to pass through the IG supplier's energy cost. Depending upon the geographic region, well over 50% of the IG producer's product price (in this case, the product is oxygen) is electricity pass through (Cvg_1 in Equation (1)). Assuming the coverage factor does not change over the life of the contract, the IG supplier is guaranteeing an energy efficiency via the escalation formula agreed to contractually.

The following simplified escalation formula (Equation (1)) only escalates the base oxygen price (the price set at the beginning of the oxygen supply agreement) as a function of electricity at the time of escalation. In actual practice, numerous other terms may be included in the formula to pass through the IG supplier's cost changes in such areas as labor, taxes and maintenance and repair (M&R) costs.

$$O_2Price_n = O_2Price_b \times [Cvg_1\,(PWR_N / PWR_B) + (1 - Cvg_1)] \quad \textbf{(1)}$$

Where:

- O_2Price_n is the new oxygen price resulting from the pricing escalation, administered at a frequency as defined in the agreement (for example, once per month)
- O_2Price_b is the base oxygen price as set forth in the supply agreement
- Cvg_1 is the coverage factor (or multiplier) associated with electricity passthrough
- PWR_N is the electricity price at the time of each escalation
- PWR_B is the electricity price assumed at the time $Price_{base}$ was established

To account for changes in the cost of electricity during the term of the agreement, the IG supplier and consumer usually agree on a published index or schedule from the appropriate utility to represent the IG supplier's power cost (PWR_B above) associated with the base oxygen price (O_2Price_b). At a frequency set forth in the agreement, the then-current index (PWR_N) is used to determine the new oxygen price at the time of each escalation. Although this method is common, it can become problematic over a long-term agreement, because the index may not accurately reflect the actual cost of electricity being purchased by the IG supplier.

However, the key issue with the above escalation approach is that it does not capture a core competency of the industrial gas industry — that is, the ability to obtain low-cost power. While power supplier (utility) rate structures and power procurement strategies are beyond the scope of this article, it is fair to say that the IG industry is exceedingly knowledgeable in power procurement, as well as negotiating with utilities for specialized rate schedules and other incentives, where appropriate. Historically, electric power suppliers value the ASU's power load because of its size (routinely over 50 MW) and its high load factor. Going forward, however, the ASU's ability to quickly shed load by utilizing its liquid backup system(s) brings even more value to the utility (as more intermittent generation sources, such as wind and solar, are added to the grid). This ability to quickly interrupt allows the IG supplier to look at numerous rate schedules from the power supplier (such as time of day or interruptible rates), as well as provide flexibility to act as reserve load that the utility may shed when the grid becomes stressed. Depending upon the geography and specific utility, it is not unreasonable to expect power savings of well over 30% by employing such opportunities. And as noted above, such power-cost improvement translates to a savings potential of well over 15% in the consumer's oxygen price.

FIGURE 3. Cryogenic liquid tanks hold large quantities of industrial gas for ASU backup or for merchant supply needs

If the consumer and IG supplier have entered into an arrangement where both parties are incentivized to aggressively pursue low-cost electricity (and incentives from the power-providing utility), it probably makes more sense to escalate the oxygen price based upon the IG supplier's actual cost of electricity, rather than utilizing an index or utility rate schedule for PWR_N and PWR_B. This WACOE (weighted average cost of electricity) approach assures the pricing escalation is accurate and allows the IG supplier to aggressively pursue utility incentives that are ultimately reflected in the consumer's cost of oxygen. If the gas user has a concern regarding the validity of such WACOE data, they can always include audit rights in the product supply agreement as recourse.

Note that if the IG supplier includes merchant liquid in its scope, it is a good indication that the consumer's and IG supplier's power-procurement interests are aligned. The IG supplier desires low-cost power to improve business margins when selling LOX, LIN and LAR to third parties. The CPI operating facility benefits from a lower oxygen price on the baseload demand of the facility through lower power passthrough costs.

Although understanding the various energy rate schedules and incentives is typically a commercial conversation between the IG supplier and the utility, the operating company's technical team is essential here to assure the size of the backup system results in an acceptable risk profile for the power-procurement strategy implemented. This is discussed in further detail in the following section.

On-site facility backup considerations and shared CapEx opportunities. The benefits discussed in the previous two sections cannot occur without a detailed analysis and appropriate sizing of the IG on-site liquid-backup system. The backup system is also critical in assuring the IG plant can meet the oxygen availability requirement for supply to the consumer's facility in the event of planned or unplanned ASU downtime.

Most ASUs utilize large LIN and LOX storage tanks with natural gas vaporizers for immediate backup supply. The liquid-backup system assures continuous gas supply to the consumer in the event of a power interruption or ASU planned or unplanned outage. Typically, the backup tank is an LR (liquid reservoir) designation, which is a stick-built tank designed to hold large quantities of LOX or LIN at low pressure (Figure 3). An LR-100 for example is sized to hold a quantity of LOX that, when vaporized, is 100 million standard cubic feet of gas.

It is important to understand that LR tanks scale very efficiently (in the experience of the author, at less than a 0.6 scaling factor). Like the ASU product line, they tend to follow standard design sizes and need relatively minor customization from location to location (apart from wind and geotechnical considerations, which influence the

foundation and vessel-shell details).

There are at least two considerations which influence backup system sizing:

Consumer availability requirements: It is important to understand from the IG supplier the reliability expectations and guarantees of the ASU (greater than 98% is typical). Assuming the consumer needs availability approaching 100% (excluding planned, joint outages), one aspect of the LR design must include such storage to meet this differential between the ASU's anticipated reliability and the consumer's required availability.

Capturing power incentives: In addition to time-of-day rates and load shedding incentives from the utility supplying the on-site plant, additional savings may be available on the demand side by shedding load during peak electricity usage periods. And while each cost savings opportunity has a quantifiable benefit, each also has an associated risk profile. The consumer's technical team needs to work with the IG supplier (and utility) to understand the risk-reward profile for each power savings opportunity and agree on the appropriate increases in LOX and LIN storage to support.

One final consideration in backup-system sizing is the time needed to initially fill and to refill the selected LR tank following an ASU outage or power reduction. Desired fill time may also impact the ASU's liquifier design and even impact the ASU size itself to assure adequate peaking volumes are available. Keep in mind that while third-party merchant liquid may be present in the area for purchase, its availability may be significantly limited if stress on the grid is widespread. There are many considerations when sizing the LR system, and, in the opinion of the author, design tradeoffs and optimizations can only occur here if joint discussions occur between the consumer's and IG supplier's engineering and commercial teams.

Finally, besides CapEx benefits that may exist from sizing the LR tank(s), keep in mind that joint infrastructure savings are likely if the CPI facility and ASU construction periods overlap. Since the ASU will probably share utilities with the consumer, the project teams should evaluate CapEx sharing opportunities in areas such as electrical substation facilities, high-voltage transformers, and coordination and sharing of utilities, such as potable water, cooling water, and storm and sanitary sewer. The CapEx savings may be significant if bundling opportunities exist rather than if executing the ASU as a stand-alone project.

Questions for discussion

Overall, selecting an industrial gas supplier for an on-site facility should consider technical and commercial integration opportunities between the consumer and IG facility. Such potentials are not readily defined through the RFP process but through an optimization procedure occurring downstream of the initial RFP. The technical and commercial optimization discussions should result in an understanding between the parties in the following areas:

- Will the IG supplier expend CapEx to meet the consumer's baseload requirement and allow the IG supplier to provide merchant products (and potentially, gas products) to third parties in the area?
- Is the power-purchase strategy understood and agreed to by the parties? Are the parties aligned on expected electricity-cost savings, associated risk and the manner in which the power pass through is administered for oxygen pricing escalation?
- And finally, are the parties aligned on the design of the liquid backup systems (and ASU peaking capabilities) and the way in which they will be used to pursue OpEx savings with respect to power? Have the parties evaluated other CapEx savings opportunities that may occur due to joint project execution of the ASU and consumer facility?

When each IG bidder's scope and optimization approach are understood, the consumer should then be in position to select the IG supplier that brings the best value proposition to the consumer, while understanding and accepting the associated risk profiles for those savings opportunities captured. ■

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Production and Demand Challenges for 'Green' Hydrogen

Burgeoning demand for hydrogen to support decarbonization goals is straining existing supply chains for industrial gases and prompting companies to adapt quickly to the emerging net-zero-carbon economy

Rudy De La Fuente
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IN BRIEF

HYDROGEN SUPPLY CHAIN: A COMPLEX WEB

DEMAND FROM MOBILITY SECTOR

WAVE OF TRANSFORMATION

The increasing use of hydrogen as a clean energy carrier is causing a transformation in the industrial gas sector — putting the resiliency of supply chains to the test, posing a challenge to the gas-production dynamics of the past and sparking a need for new levels of adaptation and collaboration for the future.

Prior to the recent increase in hydrogen demand, the gas has been a critical feedstock for producing ammonia for over a century, helping to enable global population growth to more than 8 billion people. In addition, hydrogen has been key to vehicle fuel production and is important to the food and pharmaceutical industries.

The traditional methods for producing and utilizing hydrogen are inextricably linked to carbon emissions. Most past and current hydrogen production has been based on steam reforming of natural gas (gray hydrogen). In recent years, producing hydrogen with electrolyzers powered by renewable energy (green hydrogen) has become more important because of its ability to produce H_2 from water without CO_2 emissions.

Emerging trends in the mobility sector are rapidly increasing demand for green hydrogen, placing new constraints on the hydrogen supply chain. These trends extend to fuel-cell-powered vehicles and to sustainable aviation fuel (SAF), which looks to decarbonize via the power-to-liquids (PTL) route, for example. The greater demand creates additional pressure on a hydrogen market that is already short on molecules and equipment for producing green hydrogen (Figure 1). One thing is certain: while companies adapt their hydrogen strategies against a net-zero backdrop, it will be essential for all industry stakeholders who are looking to prosper in a constantly changing market to keep up with the latest advances.

FIGURE 1. Emerging trends, such as making sustainable aviation fuel via the "power-to-liquids" route, puts pressure on the hydrogen market, which is already short of molecules and equipment

Irrespective of the hydrogen production route (green, blue, turquoise, gray, or others), the gas plays key roles across multiple sectors, and continued demand pressure for this molecule should be expected (for more on the different "colors" of hydrogen, see Refs. 1–3). It is important to explore the implications of a hydrogen demand that outstrips supply, creating challenges in the market, especially via emerging markets in the mobility sector.

H_2 supply chain: a complex web

The industrial-gas supply chain, which consists of a complex web of producers, distributors and storage manufacturers, has traditionally centered around a select group

of major companies in the hydrogen arena. As nations adopt green hydrogen as part of their decarbonization efforts, these players are struggling to deal with such demand. The demand creates new challenges, such as delays in projects by new market entrants, while simultaneously placing the stability of new hydrogen supply in question. According to recent personal experiences, the lead times for industrial-scale electrolyzers have increased by as much as 50% over the past two years. The increase indicates that the supply chain is under substantial strain as green hydrogen production is scaled up.

Governments around the world are enacting policies and incentives to support the development of green hydrogen technologies, further catalyzing increasing demand. Governmental policies include financial incentives, subsidies, tax credits and regulatory frameworks aimed at promoting renewable energy deployment, electrolyzer manufacturing and hydrogen infrastructure development. Although the policies help to decarbonize economies, they nevertheless create pressure that materially impacts the green-hydrogen supply chain.

Particularly noteworthy is the fact that a new group of market actors, invigorated by the promise of hydrogen, is exerting supply pressure on hydrogen equipment manufacturers. The current spike puts a burden on the restricted manufacturer base (more on this topic is to come), which results in bottlenecks that reverberate across the supply chain. As a result, some orders are delayed for months, or even years. On the other hand, electrolyzers are not the only example of how these disruptions manifest. Case studies have shown that fuel-cell projects have been delayed recently due to a lack of high-purity hydrogen. This demonstrates the practical impact that these disruptions have.

To effectively handle the surge in demand for H_2, it is necessary for the industrial-gas supply chain to facilitate collaboration and quickly react to the changing landscape. Potential strategies include increasing the scope of manufacturing capabilities, making investments in technological advancements and cultivating a more diversified supplier network. There have been instances of such successful industry-wide moves beginning to emerge, such as partnerships between gas suppliers and renewable-energy corporations to stabilize the supply of hydrogen. In other situations, businesses that specialize in the distribution of electrons are also following the molecule. An example of this is the renewable-energy company NextEra Energy (Juno Beach, Fla.; www.nexteraenergy.com), which announced plans for a green hydrogen project last year [*4*] and reportedly plans to invest $20 billion in the hydrogen market [*5*].

FIGURE 2. Making sustainable aviation fuel made from carbon dioxide requires pure hydrogen

This is a notable example of how companies that have access to renewable energy, such as NextEra, can effectively carve a path to produce hydrogen that diverges from the industrial gas majors. This is due to the fact that electricity places a heavy burden on green hydrogen projects from an operational expenditure standpoint. Thus, companies that have historically focused on electricity, but have access to renewable electricity can enter the market to supply additional streams of green hydrogen while controlling the bankability of their projects from an expenditure perspective. As a result, companies like NextEra have the ability to supply hydrogen to not only conventional markets, but also new ones that are emerging in the hydrogen mobility sector, for instance.

Demand from mobility sector

In the same way that there are only a few producers of electrolyzers, there are also only a few manufacturers of fuel cells. The market for hydrogen fuel-cell vehicles is beginning to gather pace, particularly when it comes to heavy-duty transportation. It is true that there are new producers of fuel cells, but only a small

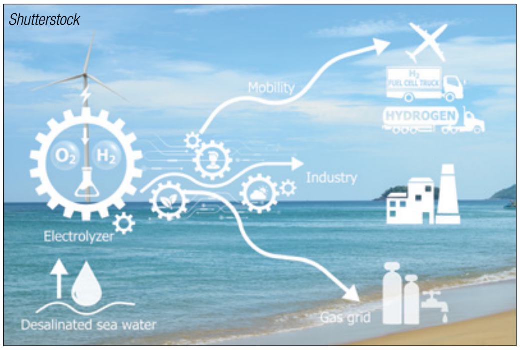

FIGURE 3. The hydrogen industry is characterized both by challenges and opportunities

number of these manufacturers have a lengthy history of being able to produce a trustworthy final product. This can restrict alternatives, given that selecting a company that has been tried and tested reduces investing risks. When it comes to its heavy-duty transportation fleet, truck manufacturer Kenworth Trucks Co. made the decision to implement Toyota's fuel cell technology as part of their debut. Cummins Inc. (Columbus, Ind.; www.cummins.com), a well-known name in the diesel market, recently acquired Hydrogenics, a developer and manufacturer of fuel cell components and hydrogen production equipment. The acquisition has enabled Cummins to have access to both fuel cells and electrolyzers. This alternative method of derisking heavy-duty transportation is a result of Cummins' strategic acquisition of Hydrogenics.

Additionally, as a result of the developments in this area, a knock-on effect is occurring, in which the demand for fuel cells for heavy-duty transportation is driving the need for carbon-fiber storage containers. Critically, these vessels are essential for reducing the weight of a vehicle, as well as the amount of hydrogen it carries. Nikola Corp., maker of fuel-cell commercial vehicles, has a heavy-duty fleet that represents an example of the ongoing trend toward higher pressure requirements. The fundamental goal of high-pressure hydrogen storage is to give a vehicle a greater range before it is necessary to refill it with hydrogen. Because of this, there is an increased strain placed on the supply of high-pressure equipment. Several new suppliers are increasing their efforts to manufacture carbon fiber vessels in a more expeditious manner to meet the high-pressure requirement being witnessed.

Hydrogen compression-focused businesses are likewise making attempts to fulfill this requirement.

Furthermore, the aviation industry, which also falls under the mobility sector, is displaying an increased requirement for SAF, an essential element of the aviation industry's attempts to minimize its carbon footprint. The manufacture of SAF is dependent on green hydrogen when using the PTL pathway (there are various means of creating SAF apart from this pathway, however, PTL requires pure hydrogen). Synthesis gas (syngas) can be produced by converting incoming streams of hydrogen and carbon dioxide into syngas, typically in a ratio of 2:1 H_2 to CO.

It is essential to detail that the process of manufacturing SAF through the PTL route can be accomplished by the reverse water-gas-shift method, which is a new technological advancement being developed by key industry players, such as Technip Energies. Following this, additional steps, such as Fischer-Tropsch (F-T) synthesis and hydrocracking, are carried out to generate SAF. Currently, SAF accounts for only 3% of the total fuel used in aviation [*6*]. The aviation sector is under increased pressure to reduce its carbon emissions and make the transition to less carbon-intensive fuels, so demand for SAF among aircraft builders and airlines is increasing.

A recurrent pattern emerges: as the use of SAF becomes more widespread, the demand for the environmentally friendly hydrogen required to manufacture it also rises. However, SAF is just one example of what can be created by the PTL route when utilizing the F-T process, as other derivatives can equally be generated, such as naphtha (which serves many industries), and sustainable diesel for vessels and vehicles.

SAF has proven that it can be utilized as a drop-in replacement fuel, as shown in a recent SAF-powered flight

in Japan orchestrated by Velocys plc [7] . More recently, the first transatlantic flight on 100% SAF was recently achieved, which creates a scenario where this market continues to see an uptick. Consequently, the attraction of sustainable fuels using hydrogen coupled with carbon dioxide is increased, since they are able to function within existing mobility infrastructure as a drop-in replacement fuel.

The next ten years will be extremely important to monitor since drop-in fuels have the potential to supply fuels not just for the land and road sectors, but also for the maritime sector. Because drop-in fuels are compatible with the infrastructure, their use in existing vehicles and engines has significant advantages.

While many automobile manufacturers are considering electric vehicles, automaker Porsche is pursuing the use of sustainable synthetic fuels in its internal combustion engines through a process known as methanation [8].

Drop-in fuels can be utilized in traditional combustion engines, turbines and other applications without requiring significant modifications. This compatibility promotes the feasibility and scalability of drop-in fuel adoption across a variety of industries, which in turn makes it easier to make a seamless shift to energy sources that are more environmentally friendly. Such an approach counters that of some developing nations, in which internal combustion vehicles will be banned, representing a seismic shift for the automotive industry, which has relied on combustion engines for over a century. In the case of synthetic e-fuels as drop-in replacements, automobile manufacturers would not have to entirely retool their production lines, nor overhaul their supply chains to meet the growing demand for electric vehicles.

Wave of transformation

The emergence of hydrogen is causing a reevaluation of methods and models that have been in place for a particularly extended period. This, in turn, is creating a wave of transformation to sweep through the hydrogen sector, its supply chain and the future use cases for hydrogen. Currently, the industry's horizon is teeming with opportunities, as well as challenges (Figure 3). The journey of green hydrogen is still in progress, and each step discussed here contributes to the development of future economies, including a future net-zero economy. Observers and professionals in the sector alike ought to take note of these changes, as they will play a significant role in this decade, and those to come. ■

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Modern Fermentation and Fermenter Design

With the growth of 'white biotechnology,' industrial fermentation processes and large-scale fermenters will play a key role. Presented here are some design considerations

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In fermentation, microorganisms, animal and plant cells are used to produce chemical compounds. Enzymes, pharmaceutical ingredients, amino acids or vitamins, as well as various monomers are manufactured on the basis of renewable resources as metabolic products. Bioprocesses based on fermentation are becoming more and more popular in industry, not only because of their environmental friendliness and energy efficiency, but also because they can be carried out in very simple and efficient bioreactor systems.

The necessity for industrial chemistry to move to energy-efficient processes and renewable, bio-based products induces a lively development activity in the field of industrial fermentation. In recent years, besides the classical aerated fermenters there are also new fermenter concepts coming into play.

Examples for such modern fermenter concepts are the following:

- Power-to-food fermentation, which involves microorganisms that synthesize proteins only from gases like CO_2, O_2 and H_2 used in the manufacture of plant-based meat, for example
- Power-to-gas fermentation, involving microorganisms that, for example, produce methane from H_2 and CO_2 in a very energy efficient way — a quite promising method for energy storage.

The development of new processes always requires a safe scaleup from laboratory to production scale [*1*]. Today, fermenters in world-scale plants reach sizes of several hundred cubic meters, and for low-viscosity processes based on bacteria, of more than 800 m^3. However, fermenter sizes of considerably more than 1,000 m^3 are being examined in feasibility studies.

For these new fermentation processes, it is therefore necessary to examine to what extent the existing know-how, for example, for stirred, aerated fermenters or hydrogenation reactors, can be used for a safe scale-up and which new requirements have to be considered.

Aerated fermenter design principles

Many aerobic-fermentation processes are operated very efficiently in stirred, aerated fermenters. In general, the requirement for a fermenter is that it provides conditions for a high productivity of the microorganisms. This includes the optimal concentration of the components required for the metabolism, such as dissolved O_2 or various nutrients and substrates. To achieve this, added air as the O_2 source must be dispersed, and additives, such as nutrients and pH-regulating substances, must be efficiently homogenized. Another crucial requirement is a constant and homogeneous temperature field throughout the entire fermenter. Among numerous energy sources and sinks, the metabolic heat, together with the energy dissipated by the agitator, are usually the dominant energy sources to take into account in the energy balance.

The fermenter design and scale-up is based on the target productivity, which decisively correlates for a given bioprocess with the volumetric oxygen uptake rate (*OUR*),

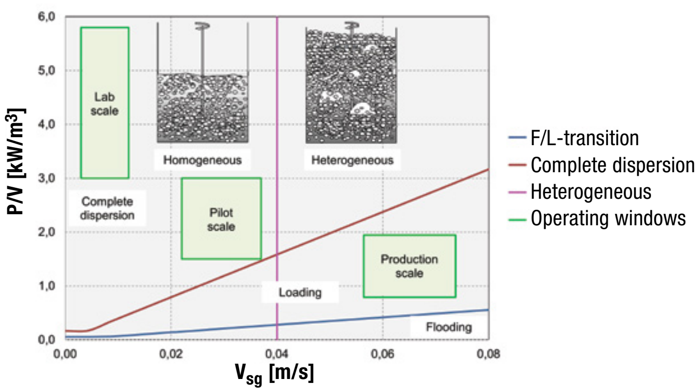

FIGURE 1. This flow map of agitated fermenters shows a transition from the homogeneous-flow regime and complete dispersion condition in laboratory and pilot scale, to an operation in the heterogeneous-flow regime and loading condition in production scale

FIGURE 2. This 2-m^3 fermenter model is used for research and development with model fluids

which varies with batch time. To comply with the mass balance, the volumetric air feed rate, *vvm*, is usually kept constant during scaleup, as shown in Equation (1):

$$vvm \sim \frac{\dot{q}_N}{V} \sim \frac{\dot{q}_N}{d_1^3} = const. \quad (1)$$

with the normalized gassing rate, $\dot{q}_N$, the liquid phase fermentation broth volume V and the internal fermenter diameter d_1. Under these conditions, scaling up with geometric similarity results in a linear increase of the superficial gas velocity, v_{sg}, with the vessel diameter, d_1, as

$$v_{sg} = \frac{\dot{q}_N}{A} \sim \frac{d_1^3}{d_1^2} = d_1 \quad (2)$$

where A is the cross-sectional area of the fermenter. The volumetric oxygen transfer rate, *OTR*, through the gas-liquid Interface is determined from Equation (3):

$$OTR = k_L a\,(c^* - c_L) \quad (3)$$

OTR must satisfy the volumetric oxygen uptake rate *OUR* of the microorganisms. The difference between the saturation concentration, c^*, and the liquid bulk concentration, c_L, represents the driving force for gas-liquid mass transfer. The gas-liquid mass-transfer capacity for agitated processes, $k_L a$, can be correlated by Equation (4):

$$k_L a = k \left(\frac{P}{V}\right)^{\alpha} v_{sg}^{\beta} \quad (4)$$

where k, α and β vary over a wide range depending on the gas-feed device, impeller type and material properties, such as the coalescence behavior of the gas-liquid system [2]. Following the above-mentioned scale-up rule and target, the power-to-volume ratio, *P/V*, can clearly be decreased with increasing scale. This is first of all because v_{sg} increases with scale ($\sim d_1$) and also since the average hydrostatic pressure in the larger tanks operated at higher liquid level results in an increased saturation concentration, c^*, and therefore driving force $c^* - c_L$.

This leads to operation windows, according to Figure 1, with reduced specific agitator power and higher gas velocities going from laboratory through pilot to production scale. This trend can lead to a drastic change in hydrodynamics. Figure 1 shows a typical scenario with a transition from the homogeneous-flow regime and complete dispersion condition in laboratory and pilot scale to an operation in the heterogeneous-flow regime and loading condition in production scale. This means that the bubble-size distribution is narrow, and the bubbles are rather evenly dispersed in the small-scale fermenter. In production scale, large bubbles appear, and an increasingly inhomogeneous local distribution of the gas phase can occur. Finally, flooding must be strictly avoided, as gas-liquid mass transfer would drastically break down. The flooding limit can be shifted towards higher gas flowrates when using modern concave-type impellers instead of the traditional ones, such as, for example, flat blade disc (Rushton) turbines or pitched-blade turbines. The effect of the interaction of the impeller type with, for example, the feeding device or internal heat exchangers and the influence of the operation range on the agitator system performance can be investigated with model fluids in sufficiently large scale of ~1 m^3 as shown in Figure 2. This allows a comparison of agitator and fermenter systems regarding the general flow pattern with possible stagnant areas, gas-liquid mass transfer and blend time.

Process design for pure gases

Fermentations with pure gases have recently become increasingly important. Examples are power-to-food or power-to-gas processes. These processes have both similarities to traditional aerobic fermentations and significant differences that are more reminiscent of pure gas reactions such as hydrogenation. Many of these new processes have so far been operated on a pilot scale or smaller production scales. To benefit from "economies of scale," the understanding of these processes still needs to be significantly improved. However, the experience already gained with aerobic fermentation and reactions with pure gases can be helpful. Reactors are therefore used for pure gas reactions, using gas recirculation from the headspace. This variant is particularly suitable for processes in which the gas supplied to the process needs to be completely converted. The fresh gas is usually introduced into the bottom of the reactor and split into small gas bubbles by a primary disperser. At the same time, unreacted gas is redispersed from the headspace via a hollow shaft using a self-inducing impeller

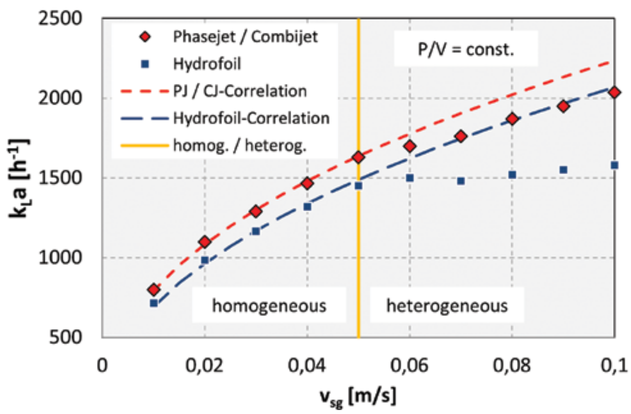

FIGURE 3. The impact of heterogeneous-flow conditions on the $k_L a$ value can be seen here

FIGURE 4. Shown here are two high-performance impellers for fermentation processes (left: Phasejet, right: Combijet)

type (see upper impeller in Figure 6).

An assessment of the fermenter performance can be defined analogous to the *OTR* in aerobic fermentation for a suitable gas component (educt or product)

$$GTR\ (Gc_i) = \left| \frac{\dot{q}_{Gc_{i,out}} - \dot{q}_{Gc_{i,in}}}{V_L} \right| \quad (5)$$

where *GTR* is the volumetric gas transfer rate, $q_{Gc,i}$ the volumetric flowrate of the gas component *i* relative to the input (in) and output (out) of the fermenter and V_L the volume of liquid in the fermenter. To optimize the *GTR*, on the technical side, the mass transfer of the supplied gas components from the gas to the liquid phase, which is necessary for product formation, must be maximized. On the biological side, suitable microorganisms must be used or developed that enable the highest possible absorption and conversion of the gas components into the product.

As for aerobic fermentations the volumetric gas transfer rate can be described by Equation (6):

$$GTR\ (Gc_i) = k_L a\ [c^*\ (Gc_i) - c_L\ (Gc_i)] \quad (6)$$

The term $c^*(Gc_i)$ is the saturation concentration of gas component *i*, and $c_L(Gc_i)$ the liquid bulk concentration of gas component *i*. The gas-liquid mass transfer capacity, k_La can be determined from Equation (4) and is hence affected by the same parameters.

The main limitation of *GTR* could be the very low solubility of a gas component used in the aqueous fermentation broth. Hydrogen, for example, has a solubility that is over 100 times lower than for carbon dioxide.

Mixing concept and scale-up

When scaling up a fermentation process, the goal is often to keep the volumetric transfer rate of the gaseous components, and thus also the volumetric uptake rate and conversion of the gas component by the microorganisms, at least constant. To achieve this, the concentration of the biomass and the gassing rate per volume of fermentation broth, *vvm*, are kept constant. As described in Equation (2), this prerequisite results in an increased superficial gas velocity, v_{sg}.

Typically, the main mixing task is to efficiently disperse the added gas to ensure a sufficient gas/liquid mass-transfer interfacial area. This is a function of the specific power input and, equally important, the impeller and geometric fermenter setup.

One important process parameter to be considered while scaling up is the transition from homogeneous to heterogeneous flow (upper magenta line in Figure 1), which takes place in pure water at v_{sg} ~0.05 ms^{-1}. In non-coalescing liquids, the transition can occur at significantly lower v_{sg} [*3*]. The k_La correlation found in the homogeneous regime cannot be extrapolated to the heterogeneous regime. When passing the transition from homogeneous to heterogeneous flow, the k_La correlation may change drastically or even break down completely for some impeller systems (Figure 3). In order to carry out a safe scaleup, the k_La correlation used for scaleup should ideally be based on data gained with the real gas-liquid system and the respective operating conditions in terms of *P/V* and v_{sg}, expected in production scale. In case of an operating point in the heterogeneous flow regime, the impeller choice can also become crucial (see Figure. 4). If it is not possible to carry out small-scale tests with the real gas-liquid system, it is advised to find a representative model system.

In aerobic fermentations, vessels with a large height-to-diameter ratio are commonly used. Fresh gas is supplied and dispersed in the bottom area by an impeller working as a primary disperser. Additional impeller stages ensure an intensive redispersion of the gas over the fermenter height, thus promoting the gas-liquid mass transfer (Figure 5). When it comes to the geometric design of aerobic fermenters, economic, process- or design-engineering reasons, among others, are weighed against each other, since there is no common optimum.

For fermenters that are operated with pure gases, the process requirements basically result in two possible reactor alternatives. On the one hand, analogous to aerobic fermentations, a reactor with a high aspect ratio (Figure 5) would be advantageous. In addition to the positive influence on the saturation concentration and the k_La, this will also prevent a short-circuit between the inlet and outlet flows. On the other hand, gas from the headspace could be returned to the fermentation broth using the combined gassing system commonly applied for reactions with pure gases. This setup includes a primary gas disperser in the bottom and a self-inducing gassing impeller, as in the commercial unit connected to a hollow shaft shown in Figure 6. In this way, the k_La would be increased by an increasing gassing rate using the recirculated gas from the headspace. This type has been successfully applied for hydrogenation processes for many years.

During scale-up, it must be checked whether the increasing gassing rate can still be dispersed by the primary disperser (lower impeller). If this is not the case and the primary disperser is flooded, this will have a significant negative impact on the mass transfer (k_La). The larger the aspect ratio of the vessel, the closer the oper-

FIGURE 5. This cutaway shows a concept for a large industrial stirred and aerated fermenter

FIGURE 6. This "combined gassing" concept can be applied for "pure gas" fermenters

ating point to the flooding curve.

If there is a significant difference between the inlet and outlet gassing rates due to the metabolic conversion, it must also be checked whether there are significant gradients in the superficial gas velocities in the fermenter. This would also result in significant k_La and *GTR* gradients, which must be considered in the process design and geometric optimization of the fermenter.

Apart from the challenges from the process engineering point of view, the ongoing increase in reactor sizes also bears huge challenges from the mechanical point of view.

Agitator components

The following three key factors have to be considered when designing agitator components for fermentation applications: cleanability, cost and flexibility.

Agitators must be designed to allow for thorough cleaning to prevent contamination of subsequent batches. Cleanability can be improved by using smooth surfaces, avoiding tight spaces, and using materials that are resistant to corrosion and chemical attack.

Agitator components must be cost-effective to manufacture and to install. This may require using less expensive materials or simpler designs.

Agitators must be able to be disassembled and reassembled easily for maintenance or repair. This may require using components that are not welded together.

As a consequence, there are three main approaches to design agitator components for fermentation applications, as follows:

- Gaskets are used to seal connections between components. This approach is relatively inexpensive and flexible, but cleanability might be more complicated compared to alternative approaches
- Welding components together creates a continuous, sealed surface. This is the best cleanable solution, but the least flexible
- Special solutions can be used to combine the advantages of gaskets and weldings. For example, components can be welded together with a smooth, flush surface

In addition to the design of the agitator components themselves, there are several guidelines to consider when designing the interior of a fermenter, including the following:

- Horizontal surfaces should be avoided as they might trap product residue, leading to contamination
- Surface quality is important. A polished surface is easier to clean than a rough surface

Mechanical design principles

Aerated fermenters tend to have a very low natural-vibration frequency. Main reasons for this are the usually quite large height-to-diameter ratio of the apparatus in combination with very thin vessel walls, as operating and design pressures are usually quite low.

When operating an aerated fermenter, the frequencies created by agitation run the risk of matching the natural frequency of the vessel, the agitator, or the vessel-agitator system. This can lead to strong vibration or even serious damage of the system.

To identify the natural frequency of the vessel-agitator system, it is necessary to gather information from both the agitator manufacturer and the vessel manufacturer. This can be a complex and time-intensive process.

To visualize the interaction of frequencies and agitator speed, a so-called Campbell diagram (Figure 7) can be used. This diagram shows all the excitation frequencies and natural frequencies. It can be used to identify potential resonance risks.

To take different filling levels into account, it is recommended to perform a fluid-structure interaction (FSI) calculation. This calculation uses finite element analysis to model the interaction of the fluid and the structure.

With this information, it is possible to check the agitation frequencies against the natural frequencies of the vessel-agitator system. If there is no match, the operation of the system is non-critical. If there is a match, design changes are required.

Final remarks

Industrial fermentation is becoming more and more important in the chemical process industries. The

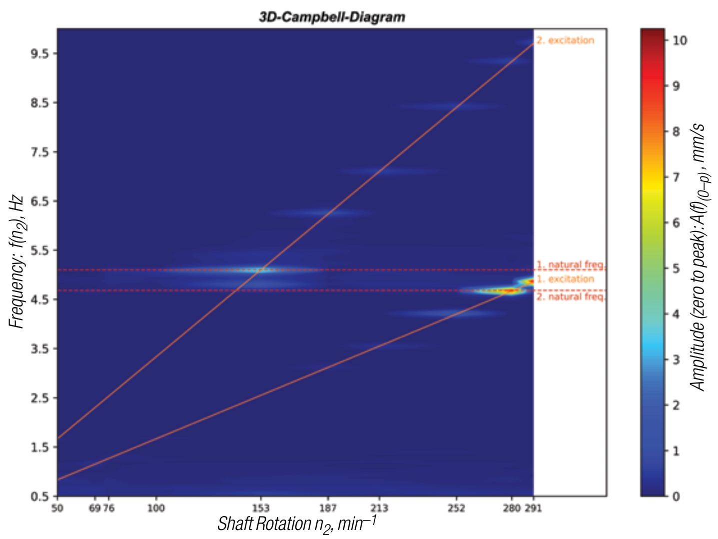

FIGURE 7. The Campbell diagram can help visualize the interaction of vibration frequencies and agitator speed, which enables the identification of potential resonance risks

main reason for this: as a bio-process, it is "copied from nature" and therefore an energy-efficient alternative to produce a lot of important chemicals and intermediates — in direct competition to the classical chemical synthesis. Therefore fermentation helps to provide more energy efficient production routes with a much better ecological footprint.

The better the fermentation process is understood — and the earlier the significant process parameters are identified — the quicker and smoother the development and scaleup of an industrial fermentation will proceed.

Economies of scale are crucial for industrial fermentation because they allow for higher production volumes, lowering the cost per unit of the fermented product. This reduction in cost enables companies to offer competitive pricing in the market, expanding their customer base and increasing profitability.

To finally engineer and build a large world-scale fermenter, the focus needs to be expanded to mechanical robustness. Besides requirements like cleanability and flexibility the fermenter needs to be set up in a way to avoid vibration or resonance risks. ■

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Selecting Mixing Impellers

Presented here is a brief overview of the considerations involved in matching the right impeller with a given application

Mark Hennis
Indco, Inc.

Matching the right mixing equipment to the material properties and desired process outcome for any liquid-mixing application is the key to project success. As new liquid formulations advance to include greater viscosities, higher solids load and other property changes, mixing processes must also adapt. Users have access to a broad range of equipment choices depending on the application. In addition to power requirements and operational standards, selection depends upon a fundamental understanding of the distinctions between types of impellers. This article explores applications, types, and the material considerations that are important for optimal impeller selection and mixer performance.

Propeller versus impeller

Although the term "propeller" is often used generically in the context of industrial mixing, it is technically a specific subset of a much broader range of mixing impeller designs (Figure 1). When thinking about propellers, most people imagine the variety that powers boats. The marine style mixing propeller is named based on its visual likeness to the common boat propeller design. This familiar geometry provides efficient flow with relatively low shear stress imparted to the mixture or batch. It is a common choice for higher-speed mixing operations focused on blending low-viscosity miscible liquids or liquids and solids that dissolve readily. It can be used successfully at either low or high speed. The most common variations of the marine style propeller include the three-blade square pitch and the steep-pitched designs. The blade angle and pitch ratio are the key differences between the two. The steep pitch pumps more liquid per revolution than the square pitch and requires more motor horsepower to do so.

How impellers work

In the context of mixing, impellers are categorized based on the flow patterns they generate. They differ in the direction of the flow they create, as well as in design characteristics, applications and efficiency.

Axial-flow impellers move fluids in a direction parallel to the mixer shaft, normally downward for a vertically mounted mixer. Axial impellers feature blades that are pitched or angled — like the marine propeller but with blade lengths and profiles that can differ significantly, based on their intended function. They are used in applications where a significant amount of fluid flow is generated, such as in large batch tanks or holding tanks that are integral to continuous processes. Examples include general product mixing, suspension of solids, and aeration or fermentation in processes like wastewater treatment or bioreactors.

FIGURE 1. This collage shows a variety of impeller designs. The term "propeller" is a subset of impellers, and they look similar to boat propellers, as seen in two of the designs here

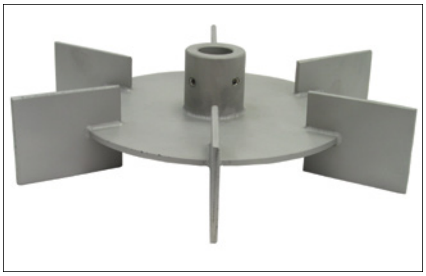

FIGURE 2. Radial-flow turbine impellers, like this one, push fluid at a right angle from the impeller shaft, out towards the wall of the container, creating high turbulence

Radial-flow impellers (Figure 2) push fluid at right angles to the impeller shaft, out towards the walls of the container or vessel. This movement creates high turbulence. They feature blades that extend radially, or outward from the center, with some designs resembling a flat-bladed fan. Radial-flow impellers can be used in applications requiring high shear, or friction between fluid layers, such as in emulsification, gas-liquid dispersion, and when breaking down solids in a liquid. Commonly used in industries like food production, pharmaceuticals and biotechnology, radial-flow impellers have multiple purposes. These range from sparging gases into liquids to generating agitation in tanks with very low volume relative to capacity.

Summarizing, the key differences between axial- and radial-flow impeller designs are the flow directions they create and their specific applications. Axial-flow impellers move a large volume of fluid efficiently, whereas radial-flow impellers focus on creating radial turbulence. The Rushton turbine, radial-flow variant, is notable for its effectiveness in fermentation and sparging applications.

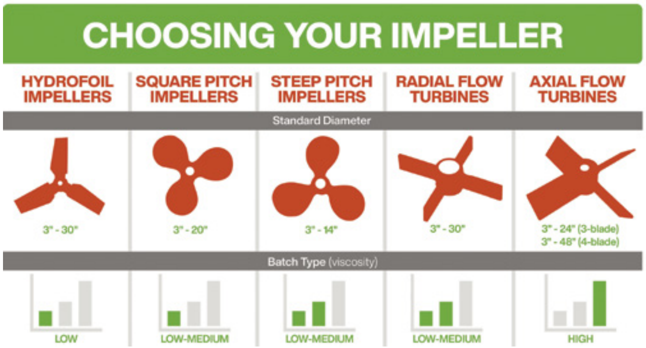

FIGURE 3. The viscosity of the fluid being mixed plays a role in the selection of the impeller type. Batch size, mixing time desired and properties of the materials also impact the type, size and number of blades on the impeller, as well as its metallurgy

Some mixing impeller designs aim to provide components of both axial and radial flow. Mixed-flow impellers, a specialty impeller design for smaller vessels, generate a unique gentle flow that is partly axial and partly radial. This offers versatility for various lower-viscosity mixing tasks. Ultimately, the choice of mixing impeller design depends heavily on the nature of the mixing process, the characteristics of the fluids involved and the desired end product.

Material considerations

Industrial mixer manufacturers offer 316 stainless steel as the standard material for parts to be submerged in a mixing application. Numerous advantages come with the application of stainless steel in mixing environments, including chemical resistance, as well as protection against rust and corrosion. For the most demanding chemical or corrosive environments, alternative materials such as Hastelloy can be used. Hastelloy is a proprietary alloy with high nickel and chromium content for superior corrosion resistance. Additionally, a variety of coatings are available to protect mixing shaft and impeller assemblies. When chemical resistance is not a primary concern, aluminum is a cost-effective alternative. Aluminum propellers provide significant savings without compromising on performance, making them a viable option for budget-conscious operations.

Choosing the right impeller

Selecting an appropriate mixing impeller involves considering the desired flow pattern, fluid viscosity and impeller geometry (Figure 3). Axial-flow impellers are suited for most liquid-mixing applications due to their vertical-flow pattern, whereas radial-flow impellers — ideal for fermenting or shallow-batch mixing — push fluids horizontally. The impeller's blade profile, width and angle are crucial in managing fluid movement, especially for high-viscosity fluids or mixtures requiring high shear. Additionally, the impeller size is directly linked to the power and torque requirements of the mixer drive system, underlining the importance of compatibility to avoid mechanical failure.

Understanding the differences between propellers and impellers, along with material choices, is vital in industrial mixing. This knowledge ensures the selection of the most suitable mixer components, optimizing performance and efficiency in various industrial processes. Recognizing these nuances is critical to making informed decisions and contributes to the success of mixing operations across diverse industries. When in doubt, consult with the applications engineers at your mixer manufacturer. They have likely dealt with similar applications many times and can be a valuable resource for providing guidance and suggestions. ■

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All figures courtesy of Indco, Inc.

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Effectively Discharging Solid Materials from Storage Bins and Silos

When considering the use of a silo discharge system to help convey materials, it is crucial to assess the specific requirements of the materials being stored, the operational goals and the overall system compatibility

Thomas Picone
Vibra Screw Inc.

Storing and handling dry bulk powders in bins and silos can lead to several different material-handling problems. These issues can impact material flow, product quality and overall process efficiency. Assuring material discharge from storage silos is crucial for many industrial processes, because it ensures a continuous and controlled flow of materials.

To address such problems, various techniques and equipment, such as mass-flow bins, bin activators, aeration systems, flow aids and vibrators can be employed to ensure reliable material flow and minimize issues associated with storing and discharging dry bulk powders from bins and silos. Careful material selection and design considerations are also essential to mitigate challenges.

This article outlines some of the equipment and technologies available to assist in material discharge, and provides guidance in selecting the most appropriate option for a particular application.

MATERIAL FLOW ISSUES

Some of the common material-handling problems associated with storing dry bulk powders in silos are illustrated in Figure 1 and described in the following sections.

Bridging. Bridging occurs when the powder forms a stable arch or crust across the top of the silo, blocking the material's flow. This can happen due to material cohesion or if the material's surface moisture has caused it to adhere to the walls of the silo.

Arch breakage. When attempting to dislodge a bridge or rathole by force, it may result in the sudden release of material, causing unpredictable and uncontrolled material flow, which can be dangerous and damaging to equipment.

Ratholing. Ratholing refers to the formation of a vertical channel down the center of the silo, leaving material stagnant on the sides. This is often caused by poor material-flow properties, such as when the material segregates and the finer particles flow preferentially.

Segregation. Some dry bulk powders can segregate within the silo, leading to uneven material composition. This results in inconsistent product quality when the material is discharged from the silo, and it can be problematic in industries like pharmaceuticals or food processing where material homogeneity is critical.

Material stagnation. Stagnation can occur when material becomes trapped in the corners or along the walls of the silo, reducing discharge efficiency. Material stagnation can lead to product contamination, spoilage and the need for manual intervention to clear any blockages.

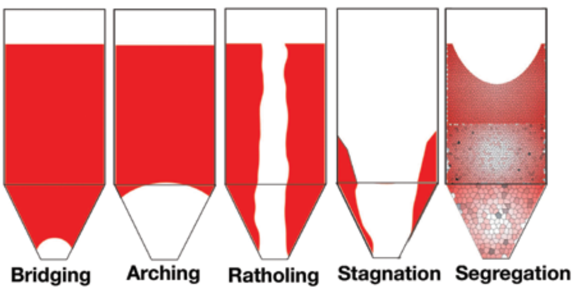

FIGURE 1. Storage of dry bulk materials in bins and silos can lead to a variety of material-flow issues that can potentially impact the product quality

Flowrate irregularities. Irregular flowrates can disrupt downstream processes and make it difficult to meet production targets. This can be caused by inconsistent flow from the silo, resulting in batching errors or process inefficiencies.

Material caking. Some dry bulk powders are prone to caking or agglomeration, especially when exposed to humidity or moisture. Caking can lead to material blockages, reduced flowability and difficulties in discharging material from the silo.

Operational downtime. Frequent material-handling issues may lead to unplanned downtime for maintenance, cleaning or clearing blockages, which reduces overall process efficiency and productivity.

SILO FLOW AIDS

Selecting the best option for your process from among the various methods to assure material discharge from storage bins and silos requires consideration of plant scale, material properties, energy consumption, safety requirements and so on. The following sections describe several types of flow aids for silos and bins.

Gravity flow (mass-flow bins)

Free-flowing material can often be discharged simply by relying on gravity, as demonstrated in mass-flow bins. The silo design can be optimized to achieve this gravity-flow effect. Beyond that, more complex and specific designs can be used to achieve mass flow and even discharge of material on a first-in-first-out (FIFO) basis. Mass flow is an important consideration for avoiding stagnation and segregation of material, which can upset a production line and affect the quality of the end product.

Designing mass-flow bins requires careful analysis of material properties to arrive at a bin geometry that encourages proper flow. These types of bins typically have different shapes

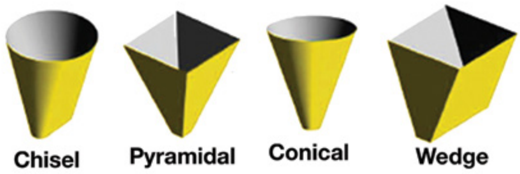

FIGURE 2. There are a number of geometry options for gravity-flow bin designs, and selection of the proper shape requires consideration of downstream processing equipment and overall plant requirements

than the common conical-bottom bins. The outlet may also have geometry other than a circular design (Figure 2). This requires consideration of overall plant design and downstream equipment to accommodate unique geometrical features.

While mass-flow bins are helpful in solving several bin flow problems, they usually cannot accommodate changing material or environmental characteristics, such as from humidity or off-specification products. Furthermore, a mass-flow bin designed for one material will most likely not be usable on another material. Below are some general considerations for installing mass-flow bins.

Higher initial cost. Mass-flow bins are typically more expensive to design and construct compared to conventional bins or hoppers. The highly specialized design and flow-control mechanisms can increase the upfront investment. Because there is no mechanical agitation to wear out or break down, maintenance costs are low.

Design complexity. Designing a mass-flow bin requires a good understanding of the material properties, flow characteristics and the specific requirements of the application. Achieving the desired flow performance can be a complex engineering task. Mathematical models for design of appropriate hopper-discharge angle have been developed, making it possible to find the hopper-discharge angle required to obtain mass flow. However, achieving proper mass flow can be sensitive to variations in design parameters, material properties and operating conditions. Small deviations from the optimal design can lead to flow issues.

Space requirements. Mass flow bins often have a tapered or conical shape, which can require more space compared to other types of storage vessels. This can be a limitation in facilities with limited space available for storage.

Mass-flow bins are effective for cohesive and non-free-flowing materials. They may not be suitable for all types of materials, particularly those with very challenging flow properties or highly abrasive characteristics.

Bulk density variability. Mass-flow bins may have limitations in handling materials with highly variable bulk densities. Material level (headload) in a bin will directly affect the density of powders. These variations can affect the flow-control mechanisms (feeders) and require constant adjustments (speed) to maintain accurate flow.

FIGURE 3. A bin activator replaces a portion of the bottom cone of a typical bin, providing vibratory action to encourage flow

Material stagnation. While mass-flow bins are designed to minimize stagnant regions, material can still occasionally become stagnant in certain conditions, leading to flow disruptions. Unfortunately, mass-flow bins are unable to be modified to improve material flow if material-handling characteristics have changed.

Despite these disadvantages, mass-flow bins remain a valuable solution for industries where maintaining reliable material flow and minimizing segregation are critical for product quality and operational efficiency. The decision to use a mass-flow bin should be based on a careful assessment of the specific material-handling requirements and a cost-benefit analysis of the investment.

Bin activators

Vibrating bin dischargers, or bin activators, are conically shaped struc-

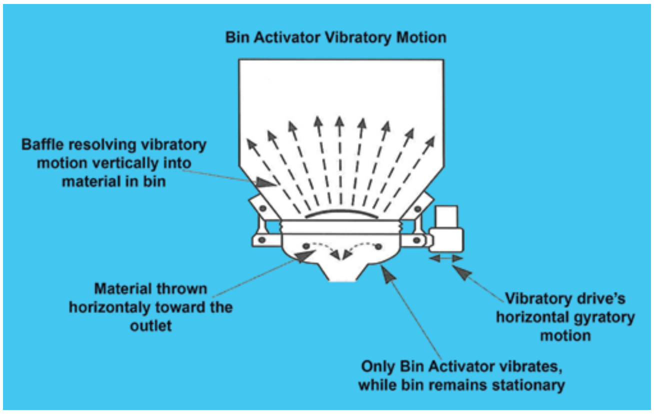

FIGURE 4. Bin activators feature internal baffling that help to avoid segregation. The device is designed so that the bin remains stationary while only the activator portion vibrates

tures that replace a portion of the lower cone of a typical bin (Figure 3). They are flexibly supported from the bin and vibrated horizontally. The vibrational forces, combined with the unit's internal geometry and baffling, provide flow of material through a bottom outlet. Unlike gravity or mass-flow bins, bin activators can accommodate a wide range of materials and characteristics. If materials or characteristics change, the vibration force can be adjusted to accommodate.

Like mass-flow bins, bin activators promote FIFO flow. Their internal baffles encourage flow from the entire bin cross-section, while the baffling also mixes material from the center and periphery to avoid segregation (Figure 4). Bin activators are sized based on bin diameter and material handled. Bin activators offer many advantages for assuring continuous material flow from storage, described below.

Cost. Cost range is based on the size of the bin discharger, which is based on what type of material is being handled and the size (diameter and straight side) of the silo. The bin activator may range in size from 2 to 18 ft in diameter.

Promotes FIFO flow. FIFO flow is crucial in many industries to ensure product quality and prevent material degradation or spoilage. Bin activators facilitate FIFO flow by consistently discharging material from the bottom, ensuring that the oldest material is the first to be discharged.

Handles cohesive and viscous materials. Difficult-flowing materials, such as clay, sludge or sticky powders, can be effectively handled by bin activators.

Uniform discharge rate. By using controlled vibration, the material being handled is conditioned to a constant bulk density by removing entrained air. Bin activators provide a consistent and controlled discharge rate, which is essential for processes that require precise material feeding or dosing. This uniform flowrate enhances process efficiency and accuracy.

Reduced material segregation. Some materials tend to segregate or separate into different particle sizes during storage or handling. Bin activators can help minimize material segregation by ensuring a consistent flow of material with minimal disturbance.

Low maintenance. Bin activators are relatively low-maintenance compared to other material-handling equipment. They have few moving parts, making them not very prone to wear and tear.

Versatility. Bin activators can handle a wide range of materials, including powders, granules and slurries, making them versatile in various industries, such as agriculture, food processing, pharmaceuticals and construction. They can be easily modified in the field should the material itself or the material-handling characteristics change.

Safety. Bin activators are generally safer to operate than some other material-handling equipment because they have fewer components that are exposed to operators and fewer risks of material spillage or dust emissions.

Environmental benefits. Efficient material handling with bin activators can lead to reduced material waste, improved product quality and minimized environmental impact.

In summary, bin activators are advantageous for handling difficult-flowing materials because they ensure consistent and controlled material discharge, prevent blockages, promote FIFO flow and are versatile and relatively low-maintenance. These benefits make them a valuable tool in industries where reliable material handling is essential.

Non-material-contact vibrators

Storage silo vibrators are used to promote the flow of bulk materials within silos, hoppers and bins. They come in various types, each designed to address specific flow problems and material characteristics.

Due to their low cost compared to mass-flow bins and bin activators, storage-bin vibrators (Figure 5) are often the first choice to help with bin flow problems. They are limited, however, in the amount of vibration that can be applied, since they directly fasten to the bin structure and if sized too large, can cause cracking and other structural problems. But for material that needs a little persuasion to get moving, they can be very cost-effective.

Vibrators generally all work with the same principle, just with differing drive mechanisms. Pneumatic vibrators use compressed air to produce linear or rotary vibrations. Device types include piston, ball, turbine and eccentric weight. The latter provides the highest force output for the toughest flow problems. Electric and hydraulic vibrators use a motor to rotate eccentric weights and are most often used for higher-vibration force applications. Electric vibrators tend to be the most energy efficient. Pneumatic and hydraulic options are less efficient due to losses associated with fluid flow.

Since they only provide external non-material contact, vibrators do not help with flow issues like segregation. They may get material mov-

FIGURE 5. Storage-bin vibrators provide a low-cost method to help with material-flow problems, but since they are directly installed onto the bin surface, careful consideration must be taken in their specification

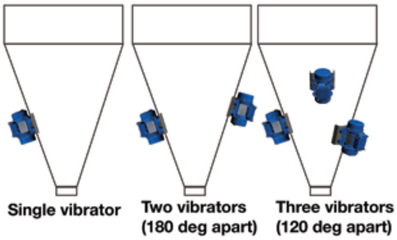

FIGURE 6. The proper geometry and arrangement of silo-bin vibrators depends on the specific flow issues that occur in the bin. However, selecting the incorrect vibrator device or installing the devices in ineffective positions could lead to worsened flow problems

ing, but it may also be segregated on discharge. The following sections list some of the most common types of storage-silo vibrators.

Pneumatic piston vibrators. These vibrators use compressed air to generate linear vibrations. They are effective for both promoting material flow and preventing material bridging or ratholing.

Pneumatic ball vibrators. Pneumatic ball vibrators use the impact of a rotating ball inside a housing to generate vibrations. They are suitable for dislodging sticky or compacted materials.

Pneumatic turbine vibrators. Turbine vibrators use high-speed airflows to create vibrations. They are often used for promoting material flow in bins and hoppers.

Pneumatic roller vibrators. Roller vibrators consist of a roller mounted on a shaft. Compressed air alternately pushes and releases the roller, creating vibrations. They are effective for materials prone to arching and bridging.

Pneumatic vibrating-piston vibrators. These vibrators combine both linear and rotational motion to promote material flow. They are suitable for challenging flow problems.

Electric vibrators. Electric vibrators are powered by electricity and typically use eccentric weights or motors to generate vibrations. They come in various designs, including rotary, linear and electromagnetic vibrators.

Hydraulic vibrators. Hydraulic vibrators use hydraulic fluid to generate vibrations. They are commonly used in applications where electricity or compressed air is not readily available.

Air-knocker vibrators. Air-knocker vibrators use short bursts of compressed air to generate shock waves within the material, helping to dislodge compacted material and promote flow.

Silo cone vibrators. Silo cone vibrators are specifically designed to be installed at the outlet cone of silos. They help prevent material blockages and ensure a consistent material flow.

The choice of vibrator type depends on various factors, including the type of material being stored, its flow properties, the size and geometry of the silo and the specific flow issues that need to be addressed. Properly selected and installed vibrators can significantly improve material discharge and prevent flow-related problems in storage silos (Figure 6). Choosing the wrong type of vibrator can exacerbate problems, sometimes making them much worse.

Vibrator energy considerations

The energy consumption of electrical vibrators and pneumatic vibrators used for silo discharge can vary significantly depending on several factors, including the type and size of the vibrator, the frequency and duration of use and the specific application.

Vibrators typically need to transmit their energy through the structure or material they are working on. This can result in a loss of power, as some of the vibrational energy is absorbed by the structure itself. This could potentially reduce the efficiency of the vibration process.

The transmission of vibrational energy through a structure can potentially lead to the propagation of cracks or wear over time. This is a concern, especially in materials that may be sensitive to vibrational forces, such as certain types of metals.

It is also worth noting the

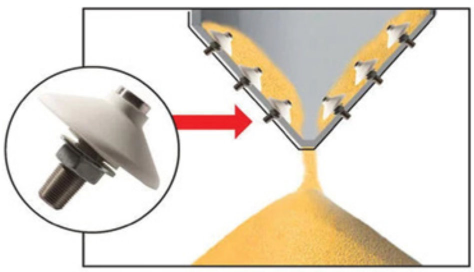

FIGURE 7. Aeration systems use streams of compressed air to help fluidize bulk materials and promote better flow

FIGURE 8. Silo air blasters are effective at dislodging immobilized materials in storage bins

potential for material damage with long-term vibrator use. Severe or prolonged use of vibrators can contribute to long-lasting damage to the material or structure. This is a significant consideration, especially if the material is prone to fatigue or if the structural integrity is crucial for safety.

Vibrators, depending on their intensity and frequency, can compact materials. In some cases, this compaction might restrict the movement of bulk materials.

It is important to note that the impact of vibrators can vary based on several factors, such as the type of material, the frequency and intensity of vibrations and the overall design and condition of the structure. Engineers and operators typically need to carefully assess these factors to minimize potential negative effects and optimize the use of vibrators for specific applications.

Energy source. Electrical vibrators are typically powered from the power grid. Pneumatic vibrators are powered by compressed air, which is generated using air compressors that consume power from the electrical grid. Pneumatic vibrators may be less energy-efficient compared to electrical vibrators because of energy losses in the air compression process and the conversion of compressed air into mechanical vibration.

Frequency and amplitude adjustment. Most electric vibrators provide adjustable eccentric weights that control the amount of force (amplitude) that is imparted into the bin structure. This allows the vibrator to match the required force to make the material in the silo flow. Many electrical vibrators offer some variable speed control, allowing users to adjust the vibration frequency as needed. This can help optimize energy consumption.

Power consumption. The power consumption of electrical vibrators can range from a few hundred watts to several kilowatts, depending on the size and power rating of the vibrator and the number of vibrators required for the application. The power consumption of pneumatic vibrators can vary widely based on factors such as air pressure, air volume, and the specific vibrator design. It can range from a few hundred watts to several kilowatts or more. The overall power consumption of pneumatic vibrators also depends on the efficiency of the air compressor system, which can vary.

In general, electrical vibrators tend to be more energy-efficient than pneumatic vibrators. However, it is essential to consider the complete system, including the energy required to generate and distribute compressed air in the case of pneumatic vibrators. Additionally, the choice between electrical and pneumatic vibrators may also depend on other factors, such as the availability of electrical power, the surrounding environment (for example, the presence of explosive atmospheres) and the specific requirements of the application.

To make an informed decision regarding energy consumption, it is advisable to consult with vibrator manufacturers, perform energy audits and consider the specific operating conditions and requirements of your silo discharge system.

Aeration systems

Aeration systems involve introducing compressed air into the bin or silo to fluidize the material (Figure 7). This can be particularly effective for materials that tend to compact or have high moisture content. Fluidization makes it easier for materials to flow out of the silo. Types of aeration equipment include fluidizers and silo air blasters.

Fluidizers. Fluidizers are a pneumatic-flow aid that use a combination of aeration and gentle vibration to promote material flow. The discs force air to move along the vessel wall, which loosens the material and prevents it from plugging or becoming compact. They can be installed outside or inside the vessel and are usually made of silicone or ethylene propylene diene terpolymer (EPDM) rubber.

Fluidizers work best with dry bulk materials that respond to gentle aeration or have a moisture content that is less than 12–15%. There are models designed for either low-pressure-high-volume or high-pressure-low-volume air, but they generally have less power and a smaller activation radius than other flow aids. Fluidizers are inexpensive and easy to install, since they only require a small hole in the silo for the discs.

A downside of using fluidizers is the limited activation radius. A greater number of units may be required to achieve the desired material flow results. Frequent replacement is another concern. They degrade quickly — even slightly uneven edges on the disks can lead to inconsistent airflow or affect its ability to seal tightly against the vessel walls. In these cases, the fluidizers must be replaced.

Fluidizers may also be ineffective for some materials. Fluidizers can only activate dry powders or light solids. They cannot be used for large particles like gravel, interlocking particles like wood shavings or fiberglass, or moist or dense material like whey. Abrasive powders degrade the nozzles

It is also crucial that air from the compressor be oil- and moisture-free, and at ambient temperatures. Otherwise, material may become contaminated or altered.

Silo air blasters. Silo air blasters (also known as air cannons) are devices used to dislodge and break up material blockages and buildups in storage silos, bins, hoppers

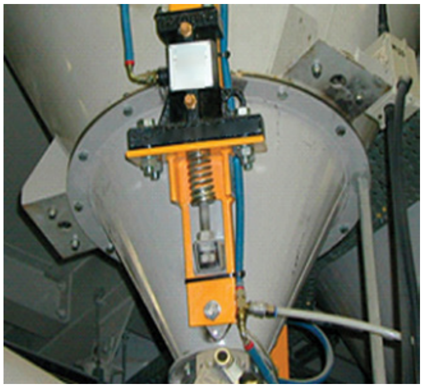

FIGURE 9. Arch-breaker devices provide direct contact with material to help mitigate material blockages at bin outlets

FIGURE 10. Live-bottom screw feeders are best employed in applications with large discharge openings. They employ several feed screws in tandem to prevent the formation of bridges or caverns in the material

and chutes (Figure 8). They work by releasing a high-pressure burst of compressed air to shock and dislodge the stuck material.

Some of the benefits of air-blaster devices are described in the following sections.

Effective blockage removal. Silo air blasters are highly effective at dislodging stubborn material blockages, including those caused by bridging, ratholing and caking.

Continuous flow. The devices ensure a continuous flow of materials from the silo, preventing production interruptions and downtime due to blockages.

Improved safety. By eliminating the need for manual intervention to clear blockages, air blasters can improve safety in industrial settings by reducing the risk of worker exposure to hazardous materials and confined spaces.

Low maintenance. Air blasters are relatively low-maintenance devices, with minimal wear and tear compared to mechanical agitators or vibrators.

Quick operation. They work rapidly, typically dislodging blockages within seconds of activation, which minimizes production disruptions.

Versatility. Silo air blasters can be used in a wide range of industries and applications, including agriculture, mining and cement production.

Despite all of the benefits of using silo air blasters, there are some downsides that must be considered.

Energy consumption. One of the main disadvantages of silo air blasters is their energy consumption. The high-pressure bursts of air require a significant amount of compressed air, which can increase energy costs, especially in large-scale operations.

Noise and vibration. The release of compressed air at high pressure can generate noise and vibration, which may require noise-control measures and isolation to minimize their impact on workers and nearby equipment.

Air-supply infrastructure. Silo air blasters rely on a source of compressed air, so they require a reliable air-supply infrastructure, including compressors and distribution systems. This infrastructure can be costly to install and maintain.

Air quality. Depending on the application, the use of compressed air may introduce contaminants into the silo, which can affect the quality of sensitive materials like food products or chemicals.

Potential material damage. In some cases, the forceful release of compressed air may cause abrasive materials to degrade or become damaged.

Material density change. Introducing air into the silo will affect the material's bulk density, making it more difficult for downstream feeding devices to maintain feed accuracy.

Air-consumption management. Properly managing the supply of compressed air to the air blasters is crucial to prevent excessive air consumption and associated costs.

Limited precision. Silo air blasters are effective for bulk dislodging, but may lack precision when compared to other methods, which could lead to over-discharge or material segregation.

In summary, silo air blasters are valuable tools for resolving material blockages in silos and other storage vessels, but their use comes with certain considerations, such as energy consumption, noise and the need for a reliable air-supply infrastructure. Properly assessing the specific needs of your application and implementing air blasters with appropriate control and monitoring systems can help maximize their advantages while minimizing their disadvantages.

Arch-breaker devices

Providing direct contact with material, arch-breaker devices or bridge-breaker agitators can be used to break up material arches or bridges that form over the outlet (Figure 9). These devices can be pneumatic or hydraulic and are designed to prevent blockages. Some installation considerations related to arch-breaker devices are described below.

Cost. For small bins where one or two arch breakers are required, the cost for the units and installation are relatively low. The unit can be custom-made to accommodate a wide range of materials and bin and silo designs. Arch-breaking screens or bars designed to be in contact with the material when vibrating should be gentle so they will not degrade powders or granules. This setup is ideal for small bins where only one or two arch breakers would be required. However, large-diameter silos will require many arch breakers to be effective, which drives up costs — not just in the initial purchase and installation, but the long-term costs for generating compressed air or hydraulic pressure. While this energy consumption is often necessary for effective operation, it is a factor to consider in terms of overall operational costs and environmental impact.

Material flow. Arch-breaker devices do not promote mass flow or FIFO flow of material. They are also not appropriate for use with abrasive materials or materials with large particle sizes.

Space requirements. Depending on the design and size of the arch-breaker device, arch breakers may require a certain amount of space for installation. In situations where space is limited, the design and placement of these devices become important considerations.

Retrofitting onto existing silos. If material-flow problems form in an existing silo, installing arch breakers can be difficult, since half the device is inside the silo and half is outside the silo. Thus, access to the inside of the silo may be difficult due to confined-space issues.

Maintenance. Like any mechanical, pneumatic or hydraulic system, arch-breaker devices may require regular maintenance to ensure proper function. Maintenance activities could include inspections, lubrication and repairs, which may add to operational costs.

Direct material contact. In order for arch breakers to work, they must be in direct contact with the material being handled. Sanitary issues may arise because material may adhere to the arch-breaker screens or bars, making the system difficult to clean.

Live-bottom screw feeders

Screw feeders or augers can be used to extract and convey materials from silos. They are effective for handling both free-flowing and non-free-flowing materials.

Live-bottom screw feeders (Figure 10) are designed for use in large silos, bins and hoppers with large discharge openings. They typically use multiple feed screws together to create a “live bottom” to prevent bridging or cavern formation. If designed correctly, bulk materials can be drawn equally from the entire width and length of the inlet opening therefore creating FIFO flow. Some of the advantages of live-bottom screw feeders are described below.

Controlled material flow. Unlike other silo-discharge devices, silo screw-bottom discharge systems are more than just a discharge device. They provide a controlled and regulated flow of materials from the silo, allowing for precise discharge rates.

Versatility. These systems are suitable for a wide range of bulk materials, making them versatile for various industries, such as agriculture, food processing and manufacturing.

Even discharge. If designed properly, screw-bottom discharge systems can contribute to an even and consistent discharge on a FIFO basis of materials, reducing the likelihood of uneven flow and potential blockages.

Automation potential. The operation of silo screw-bottom discharge systems can often be automated, improving efficiency and reducing the need for manual intervention.

Reduced segregation. The controlled discharge facilitated by screw systems helps minimize material segregation, ensuring a more uniform product.

There are also some potential issues associated with installing live-bottom screw feeders, as outlined in the following sections.

Maintenance requirements. Like any mechanical system, silo screw-bottom discharge systems require regular maintenance to ensure smooth operation. They can use multiple motors, reducers, bearings and seals that will require inspections, lubrication and occasional repairs.

Initial cost. The installation of a silo screw-bottom discharge system involves an initial investment, including the cost of the design engineering, equipment and installation. This can be a significant consideration for budget-conscious operations.

Energy consumption. Depending on the size and design of the system, there may be energy requirements associated with the operation of the screw mechanism, contributing to overall energy consumption.

Space requirements. Some silo screw-bottom discharge systems require additional space within the silo, potentially impacting the effective storage capacity.

Material compatibility. While screw discharge systems are versatile, it is essential to ensure that they are compatible with the specific characteristics of the stored materials, including particle size, moisture content and flow properties.

Potential for wear. The moving parts of the screw mechanism may experience wear over time, especially when handling abrasive materials. Regular monitoring and replacement of worn components may be necessary. ■

Edited by Mary Page Bailey

All images provided by Vibra Screw

Author

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Solids Processing

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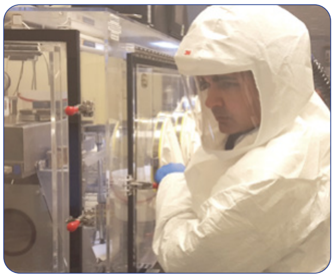

Particles – regardless of their size – play an important role in the efficiency and safety of plant operations. **Jenike & Johanson** is the world's leading technology company for bulk material handling, processing, and storage. Their skilled, highly technical team of experts and their industry-leading innovations have successfully delivered bulk material engineering solutions for over 55 years, increasing the safety and productivity of manufacturing plants across many industries.

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THE VIBRA SCREW SANITARY WEIGH BELT FEEDER

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Precision in weighing and material handling is another notable benefit of the Vibra Screw Sanitary Weigh Belt. In sanitary industries, accurate measurement and control of materials are critical for compliance with quality standards. The system provides reliable and precise weighing, contributing to the consistency and quality of the final product.

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New explosion-proof PROFOX-X actuators

AUMA's small and smart PROFOX-X actuators provide safe and precise valve control in potentially explosive atmospheres.

Electric actuator manufacturer **AUMA** has added an explosion-proof version to its successful PROFOX actuator series.

"The new PROFOX-X actuators expand all the benefits of our small and smart PROFOX actuator series to applications in potentially explosive atmospheres," says AUMA product manager Christoph Edelmann. "These versatile, future-proof actuators meet all the requirements of modern plant automation."

ATEX and IECEx certifications for the highest gas group IIC T4, which includes hydrogen, ensure safe operation in potentially explosive atmospheres.

As with the whole PROFOX line, the PROFOX-X series includes multi-turn, part-turn and linear actuators, offering automation solutions for all valve types in the lower torque and thrust ranges. Compact design makes PROFOX-X a perfect fit for tight spaces.

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The smart actuators are equally suited to OPEN-CLOSE duty and modulating applications. PROFOX actuators support fieldbus and Industrial Ethernet communication, making host system integration flexible and easy. The actuators' embedded data logging enables advanced diagnostics and predictive maintenance.

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The ideal solution for every challenge

How are granules, powders and other high-quality bulk materials efficiently stored, mixed, transported, dosed, weighed, distributed, processed and analyzed? Needless to say, the best way to do this is with solutions from the Friedrichshafen-based plant manufacturer **Zeppelin Systems**!

As a system supplier with decades of experience in the industry, Zeppelin Systems offers the ideal solution for every customer challenge along the process chain in bulk material handling "We have worked in a wide range of industries for many years, are familiar with our customers' needs and have the right solution for every challenge," says Dr. Markus Vöge, CEO of Zeppelin Systems GmbH. "To consistently and sustainably meet the high-quality demands of our customers, we manufacture process plants as well as mixers, silos and components in-house."

Friedrichshafen-based plant manufacturer Zeppelin Systems is also setting new standards in the field of mixing technology, combining its many years of expertise with the technical and technological expertise of its acquired companies Henschel and MTI. In addition to high intensity, container and horizontal mixers, the portfolio also includes heating/cooling mixer combinations. All mixers offer excellent product and result quality, high efficiency levels and modular adaptability. Also for materials that are explosive, highly flammable or toxic.

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Gentle drying under vacuum Perfect clean and contamination-free drying processes

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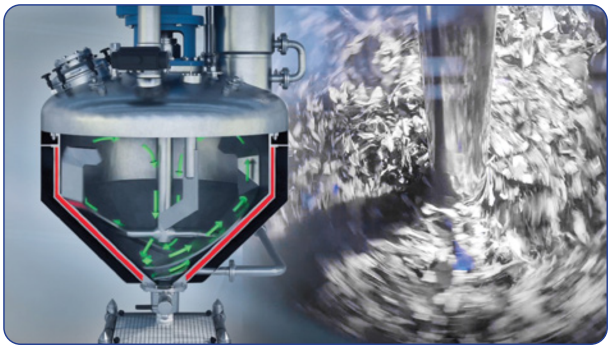
On the front, the vacuum drying ovens are fitted with a continuous mounting frame for wall installation, the frame being tightly welded to the vacuum chamber. The design of the oven is also suitable for installation and operation in explosion hazardous environments (ATEX).

These vacuum drying ovens are an indispensable feature of pilot plants, kilo labs and production installations. The VSD is ideal for GMP/FDA-compliant processes.

PINK regards the requirements of its customers as a challenge and analyzes them carefully in order to develop optimum products that are superior to standard solutions. Its extensive product range in the drying sector extends from static dryers in various designs, sizes and equipment versions through to dynamic drying systems working on different drying principles according to the customer's needs.

www.pink.de/en

Mixing solutions for battery recycling



Due to rising electric vehicle use, demand for battery materials like lithium and graphite will surge. Recycling these materials from used batteries is crucial, creating a new market with its own challenges. Besides handling discharged batteries, safety concerns include flammable solvents in the recycling process which can ignite and endanger facilities.

EKATO offers its proven SOLIDMIX technology for the pre-drying of shredded battery scrap and has optimized it for the separation of the solvents contained in the batteries. By means of vacuum drying, the solvents can be quickly and reliably separated from the battery scrap. Continuous mixing of the material to be dried ensures optimal heat transfer and distribution in the equipment, which further increases the efficiency of the drying process. Due to the modular design of the dryers, it is possible to easily scale up to larger drying capacities. Usual capacities are in the range of 0.5-4 t/h.

This not only increases safety in the subsequent mechanical separation stages, but also the quality of the separation results. In addition, the separation of the electrolytes facilitates the downstream hydrometallurgical treatment of the so-called black mass, which contains the valuable cathode and anode materials.

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Process optimization through Ex-protected data acquisition by i.safe MOBILE

The IS-TH1xx.x of **i.safe MOBILE** is a multi-functional set consisting of a high-performance handheld barcode scanner and the IS530.x industrial smartphone for reliable data capture and subsequent processing. The device can relate to suitable partner integration software. Batches of raw materials can already be scanned in the delivery area and stored in a database via the smartphone, thus ensuring seamless documentation and traceability of production processes or production orders, the raw materials and semi-finished products are usually compiled and weighed for further processing. To prevent sources of danger, mix-ups and incorrect batches, each raw material can be labelled with a QR code, storage location and other information such as shelf life, hazard warnings and special processing instructions. Each individual ingredient is scanned, and a warning appears in case of incorrect scans.

The user-friendly IS530.x smartphone is plugged into the release handle, connected to the scanner via the 13-pin ISM interface and is ready for use without the need for a separate battery or Bluetooth. The scanner (with Zebra OEM imager) captures 1D or 2D barcodes (with a range up to 6m/18m) by pressing the trigger. The captured barcode is immediately recognized and processed by the IS540.x.

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Ross SLIM Technology employs high shear for rapid and complete mixing of powders into liquids, avoiding agglomerates and dust formation

The **Ross** Solids/Liquid Injection Manifold (SLIM) is a technology for dispersing challenging powders such as thickeners, pigments and other additives using a specially modified high shear rotor/stator generator.

In an inline configuration, the SLIM mixer pumps liquid from the recirculation tank while simultaneously drawing powders from a hopper. As the liquid stream enters the rotor/stator assembly, it immediately encounters the powder injection at the high shear zone. The mixture is then expelled through the stator at high velocity and recirculated back into the tank. In a few short turnovers, solids are completely dissolved or reduced to the desired particle size (deagglomerated).

This method for high-speed powder injection is ideal for dispersing small concentrations of hard-to-wet solids like CMC or xanthan gum (>5%). It is equally effective for solid loadings as high as 70%, as in the case of some titanium dioxide or magnesium hydroxide slurries. By introducing solids sub-surface where they are instantly subjected to vigorous agitation, issues like floating powders, excessive dusting, and formation of stubborn agglomerates "fisheyes" are eliminated. Because the SLIM generates its own vacuum for powder induction and does not rely on external eductors or pumps, it is free of clogging and simple to operate.

Options include automated skid packages where the SLIM mixer is piped to a jacketed tank and supplied with flow meters, load cells, solenoid valves, level sensors and thermocouples all integrated into a PLC recipe control panel. The SLIM technology is available in batch (in-tank) design as well.

Pictured are two 25 HP ROSS SLIM Model HSM-405SC-25 with a NEMA 4 Class II, Div. 2, Group G purged control system programmed to operate both the mixer and the pneumatically-actuated 1.5" powder feed valve, managing the flow of the dry phase (powder feed hopper not shown).

Established in 1842, Ross is one of the world's oldest and largest manufacturers of process equipment, specializing in mixing, blending, drying, and dispersion. **www.mixers.com**

Solids Handling – Tailored solution for every challenge

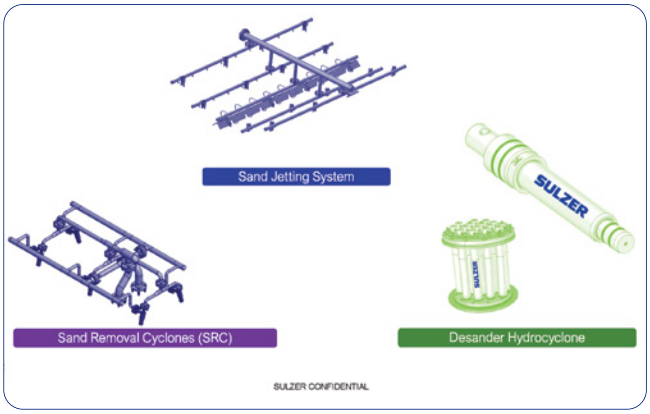
Solids handling in upstream, also known as sand treatment in the industry, has the goals to recover as much liquid (usually water) as possible for reuse as well as get the solids into a state that can be safely and easily disposed. In chemical and petrochemical processing, solid handling technologies are applied to ensure easy-to-handle solid products that are ready for sale or further processing, and clean process liquid that can be reintroduced into production processes.

Various sand handling technologies include sand jetting system, sand removal cyclones (SRC) and desanding hydrocyclones (liners):

- Sand jetting systems is the fluidization of solids by injecting water spray and simultaneously draining the slurry.
- Sand removal cyclones (SRC) is the fluidization of solids by injecting water vortex and simultaneous suction of the slurry in the vortex. The SRC system can also be installed in combination with a sand jetting system to minimize the water consumption and to increase the solids removal efficiency.

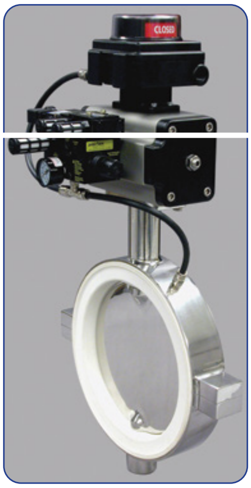
Desanding hydrocyclones (liners) utilize gravitational forces for enhanced solid-liquid separation. The installation of Sulzer's desanding hydrocyclones allows significant reduction of the size of gravity settlers, potentially eliminating the use of centrifuges typically installed for suspensions treatment, hence avoiding the hazards and maintenance associated with these equipment.

Sulzer Chemtech provides a wide range of solids handling solutions for upstream, refineries and chemical processing industries to optimize their processes as well as meet environmental regulations. They can be configurated to achieve reliable guaranteed performance in challenging and demanding applications. These solids handling technologies were proven under real field conditions and have been successfully applied in both new processes and revamps of production facilities. The automated sand separation, treatment and handling process minimize the accumulation of solids, which will adversely affect oil production over time. Advanced application knowledge together with efficient supply chain results in tailored solutions from Sulzer Chemtech for every challenge in solids handling.



www.sulzer.com/chemtech

Stainless Steel Butterfly Valve



Posi-flate Stainless Steel Butterfly Valve

The **Posi-flate** butterfly valve with a highly polished 316 stainless steel housing and disc is suitable for many applications, such as food, chemical and pharmaceutical. The inflatable seat design of the Posi-flate butterfly valve provides a better seal by utilizing air pressure to expand the seat against the disc, providing more sealing area and an even pressure distribution against the disc every time. The seat automatically compensates for wear when it inflates against the disc, extending valve life considerably. Because the Posi-flate disc only makes casual contact with the seat during opening and closing, torque requirements are substantially lower. This ease of movement also allows the disc to come to a perfect 90-degree position every time. Additionally, the smooth profile of the disc helps material flow easier and reduces build-up. The Posi-flate stainless steel butterfly valve is available in sizes of 2” (50mm) to 20” (500mm).

www.posiflate.com

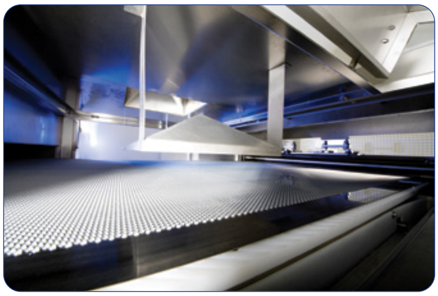
Rota-Cone® Blender

The **Paul O. Abbe** Rota-Cone® blender is the ideal choice for thorough and gentle blending of powders or crystalline products. Because this tumble blender has no shaft seals or agitator, cleaning is simplified and cross-contamination minimized. All internal surfaces the Rota-Cone® can be inspected from the single loading hatch. Liquids can be added through the optional spray line and a pin agitator can be added to facilitate liquid dispersion, granulation or de-agglomeration. Loading can accomplish with our automated drum loading and discharging system. Controls including variable frequency drive and PLC can be supplied in NEMA-4X or NEMA-7&9 explosion-proof design. Available sizes range from 0.1 to 500 cubic feet working capacity.

www.pauloabbe.com

Dry pastillation for hot melt adhesives

IPCO’s Rotoform pastillation process uses indirect cooling to deliver high quality, free-flowing pastilles



Widely used across the construction, automotive, textile, furniture and packaging sectors, Hot Melt Adhesives (HMA) offer a number of benefits over water- or solvent-based adhesives, including instant bonding, high viscosity, reusability and high mechanical strength.

EVA-type hot melts consisting mainly of a mix of paraffin wax and resin, exist in solid form at room temperature, melt when heated above a certain temperature then create a powerful bond as they cool down again.

IPCO’s Rotoform process is a dry solidification solution delivering consistently sized, hemispherical pastilles. The system uses indirect cooling – water is sprayed against the underside of a cooling belt – so there are none of the problems associated with underwater granulation, and the product leaves the system in a cold, solid (i.e. non-sticky) state.

A typical Rotoform-based HMA processing system will consist of remelting equipment for wax, a pair of mixing reactors, the Rotoform drop depositor, steel belt cooler and downstream bagging and weighing equipment.

The Rotoform deposits the hot melt onto a continuously running steel belt in the form of defined droplets. As they travel along the system, heat is transferred from the product to cooling water sprayed against the underside of the steel belt. This results in the production of consistent, hemispherical, free-flowing pastilles, with high bulk density and good packaging properties.

With no contact between the cooling water and the product, there is no risk of cross contamination and the water can be re-used over and over again. Other environmental advantages include low energy consumption, dust-free production and product, and very low vapor/gas emissions.

IPCO is able to supply complete hot melt processing plants covering everything from initial system design, through solidification, to granule packaging solutions.

www.ipco.com

LiB production: mixers for laboratory and Gigafactory

Customized particle design as the key to success

Dr. Stefan Gerl*
**The author is head of process engineering at Maschinenfabrik Gustav Eirich GmbH & Co. KG, Hardheim, stefan.gerl@eirich.de*

In the production of li-ion batteries, **Eirich** intensive mixers are convincing all along the line: from the functionalization of active material particles to the production of coating compounds for separators as well as wet to dry electrode mixtures. The adaptation of operating parameters and mode of operation alone enables users to fulfill a wide variety of tasks with a single mixer type.

Particle coating, a central basic operation in LiB production

Coating of particle systems and suspending for the production of wet electrode mixtures are central basic operations of LiB production. Eirich intensive mixers in their design as Eirich MixSolver with a horizontally arranged mixing vessel are ideally suited for suspending, but as mixers with an inclined mixing vessel they are equally well suited for coating, but above all granulating particle systems.

Coating and thus functionalizing active material particles with different nano-structured particles such as aerosils or conductive carbon blacks is a common intermediate step in the production or use of active materials. If these processes are to be carried out completely dry, without the detour via suspensions and spraying processes, mixers are needed that generate high shear rates in the powder bulk. The microgranulation die patented by Eirich also shows excellent performance in this task. The optimized shear field at the outer edges of the die breaks up the agglomerated nanoparticles so well at the appropriately selected die speed that they can dock onto the surface of the active material particles and coat them in the best possible way within a very short time.

Fig. 1: Simple scale-up from laboratory to gigafactory, e.g. from the universal 1l laboratory mixer EL1 to the 900l intensive mixer RV16 or MixSolverÒ RV12 for large-scale production. Source: Eirich

Macroscopically, this change at the particle surface is expressed by a noticeable change in the bulk density and tamped density, but also in the flow properties of the bulk. Depending on the selected mold speed and mixing time, particle systems can be designed in a simple way.

www.eirich.com

Fast-Track Your Operations with Hapman's PosiPortion Feeders

In the competitive landscape of material handling, **Hapman** sets a new industry standard with our PosiPortion Volumetric and Gravimetric Feeders—not just through performance but with unmatched lead times. When efficiency and speed are critical, our 8-10 week ship dates stand less than half the time of our competitors, ensuring you stay ahead in the market.

Why Hapman Stands Out:

- **Unmatched Lead Times**: Get your operations up and running faster with our 8-10 week delivery, a pace unrivaled in the industry.
- **Precision Handling**: Our feeders deliver exact dosing for a variety of materials, enhancing your efficiency and reducing waste.
- **Versatile and Durable**: Designed for various industries, our robust feeders ensure reliability and adaptability to your specific needs.
- **Ease of Use**: With user-friendly operation and maintenance, focus on production without the hassle.

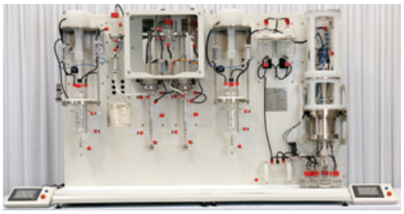
Hapman's PosiPortion Feeders are not just tools but solutions designed to elevate your business quickly. By choosing Hapman, you're not only investing in top-tier material handling technology but also in a partnership that values your time and business goals.

Don't let lead times hold you back. Contact Hapman today and leap ahead of the competition.

For more information, call 800-427-6260, e-mail sales@hapman.com, or visit hapman.com

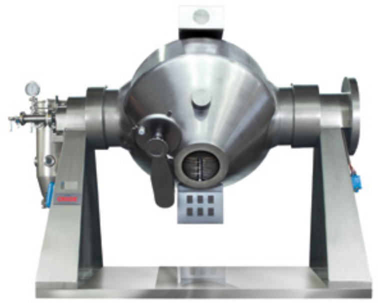
www.hapman.com

INTERPHEX



Dec-USA

Steriline North America



Italvacuum

Interphex 2024 (www.interphex.com) — a global pharmaceutical and biotechnology event — will be held April 16–18 at the Jacob Javits Convention Center in New York City. The event will feature more than 450 exhibitors, as well as a dual-track conference program (focusing on sterile and non-sterile manufacturing) and several special networking events. This Show Preview highlights a few of the exhibitors who will be present at Interphex 2024.

Flexibility is key with this new crystallization system

This company has developed a new crystallization system (photo) that combines the flexibility and robustness of batch crystallization with efficiencies achieved from fully continuous processes. According to the company, the new system can complete crystallization tasks in around 60 min typically, with the option to operate in batch or semi-continuous mode, depending on process needs. Results are consistent and repeatable due to the system's precise mixing, temperature-control and heat-transfer capabilities, as well as its high jacket-to-process-volume ratio. Its rapid, intense and homogeneous mixing ensures low crystal shear and allows for excellent particle-size control with minimal fines, resulting in a high-quality final product. The system is capable of handling material with a high solids content. With capacities ranging from 10 to 25 kg/h, the concept is suitable for a variety of production scales. Additional modules are available for larger throughputs. Stand 3629 — *Dec-USA Inc., Brick Township, N.J.*
www.dec-group.net

This robotic vial-filling machine features "levitating" platform

This company will be showcasing a robotic vial-filling machine (photo) that utilizes Planar Motor technology, a magnetically levitated transport system. The system includes a platform that levitates movers above a stainless-steel surface, providing 6 degrees of precise motion and zero friction. This allows for the transport of containers (vials, syringes, cartridges and so on) from station to station in the filling and closing operation without any mechanical components. Stand 2537 — *Steriline North America, Inc., Bradenton, Fla.*
www.steriline.it

This vacuum dryer features built-in lump-breaking units

The Criox System (photo) is a double-cone rotary vacuum dryer that includes lump-breaker units. Designed to treat wet or damp powders, such as active pharmaceutical ingredients (APIs), the Criox System has a biconical drying chamber, which can range in size from 12.5 up to 283 ft^3. Electrical-motor-driven lump-breaker blades crush agglomerates in the batch, increasing the surface area of the product that is exposed to evaporation, improving the mixing effectiveness and drastically reducing drying times. Materials of construction include stainless-steel types 316L, 304, 904L and Alloy C-22. The system can also be equipped with this company's Saurus piston-type vacuum pump, which can produce a vacuum level of 0.03 mbars. Stand 3236 — *Italvacuum S.r.L., Turin, Italy*
www.italvacuum.com

Sublimation sensors help to optimize lyophilization processes

This company has developed a new sensor capable of monitoring the advance of the sublimation front in real time for freeze-drying processes. The single-use probe, containing five independent temperature sensors with wireless communication, is placed within the vial to monitor the advance of the sublimation front, which is key to optimizing the primary drying steps in lyophilization processes. The probes are coated with an FDA-approved material and are available in five different formats to fit into any vial size from 2R to 100R. A single system can hold up to 50 probes per freeze-drying batch. Without cables or batteries, the probes work via a patented wireless power-transmission technology. They have a reading interval of 1 min and can operate in temperatures from –60 to 60°C. Stand 2453 — *Telstar Life Sciences Solutions, Bensalem, Pa.*
www.telstar.com ■

Mary Page Bailey

Advertisers Index

See bottom of opposite page for advertising sales representatives' contact information

Classified Index April 2024

FOR ADDITIONAL NEWS AS IT DEVELOPS, PLEASE VISIT WWW.CHEMENGONLINE.COM

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Economic Indicators

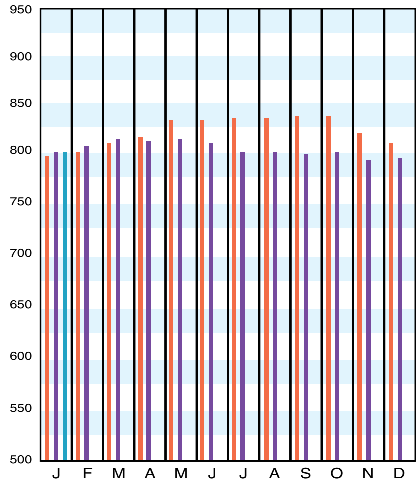
2022 2023 2024

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX® (CEPCI)

(1957–59 = 100)	Jan. '24 Prelim.	Dec. '23 Final	Jan. '23 Final
CE Index	795.1	789.6	802.6
Equipment	997.7	990.5	1,015.8
Heat exchangers & tanks	804.7	803.2	833.1
Process machinery	1,027.2	1,016.3	1,030.4
Pipe, valves & fittings	1,343.1	1,330.7	1,428.2
Process instruments	567.2	565.5	561.7
Pumps & compressors	1,522.5	1,484.2	1,389.3
Electrical equipment	810.9	807.2	795.1
Structural supports & misc.	1,103.1	1,095.1	1,113.7
Construction labor	374.4	374.7	357.8
Buildings	813.9	799.1	795.2
Engineering & supervision	315.3	315.0	312.4

Annual Index:
2016 = 541.7
2017 = 567.5
2018 = 603.1
2019 = 607.5
2020 = 596.2
2021 = 708.8
2022 = 816.0
2023 = 797.9

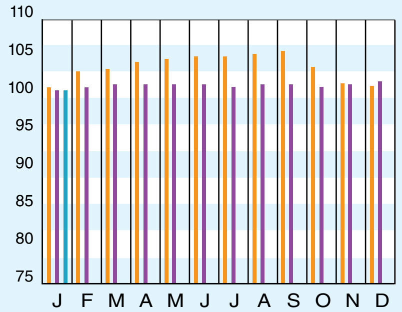


Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

CURRENT BUSINESS INDICATORS

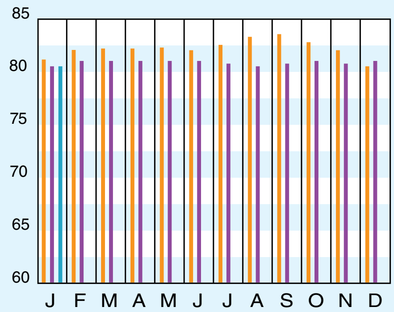
CURRENT BUSINESS INDICATORS	LATEST	PREVIOUS		YEAR AGO
CPI output index (2017 = 100)	Jan. '24 = 97.9	Dec. '23 = 99.3	Nov. '23 = 99.0	Jan. '23 = 98.9
CPI value of output, $ billions	Dec. '23 = 2,402.4	Nov. '23 = 2,397.2	Oct. '23 = 2,398.4	Dec. '22 = 2,408.5
CPI operating rate, %	Jan. '24 = 77.5	Dec. '23 = 78.8	Nov. '23 = 78.7	Jan. '23 = 79.1
Producer prices, industrial chemicals (1982 = 100)	Dec. '23 = 302.4	Dec. '23 = 308.9	Nov. '23 = 315.8	Dec. '22 = 332.2
Industrial Production in Manufacturing (2017 =100)*	Jan. '24 = 98.6	Dec. '23 = 99.1	Nov. '23 = 99.1	Jan. '23 = 99.5
Hourly earnings index, chemical & allied products (1992 = 100)	Dec. '23 = 230.7	Nov. '23 = 228.9	Oct. '23 = 224.0	Dec. '22 = 208.8
Productivity index, chemicals & allied products (1992 = 100)	Jan. '24 = 93.1	Dec. '23 = 93.9	Nov. '23 = 92.7	Jan. '23 = 91.2

CPI OUTPUT INDEX (2017 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)

CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2012 to 2017
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index® (CEPCI; top) for January 2024 (most recent available and first data available for this year) increased compared to the previous month. This increase is the second consecutive monthly rise, and is larger than the previous gain. The January increase was largely driven by increases in the Equipment and Buildings subindices. The Engineering & Supervision subindex rose slightly, and the Construction Labor subindex declined by a small amount. The current CEPCI value now sits at 0.9% lower than the corresponding value from January 2023. Meanwhile, the Current Business Indicators (middle) show decreases in the CPI output index and CPI operating rate for January 2024.